



NTPC/KGN/EMG/EC-MOEF/HYC/2025-26

Date: 01/06/2026

To,

Additional Principal Chief Conservator of Forests (C),
Ministry of Environment, Forest and Climate Change,
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3,
Ravishankar Nagar,
Bhopal-462016, Madhya Pradesh
Email id- rowz.bpl-mef@nic.in

Sub: Submission of 22nd Half Yearly Environmental Clearance Compliance Report of Khargone Super Thermal Power Project (2x660 MW) at Village Selda & Dalchi, Khargone, Madhya Pradesh by NTPC Ltd.

EC Ref: J-13012/54/2010-1A. II (T), Dated-31.03.2015

Dear Sir,

With reference to the above-mentioned subject matter and EC reference, please find enclosed the half yearly compliance status report to the stipulated conditions of Environmental Clearance for the period (Oct'25-Mar'26).

Submitted for your kind information and records please

Thanking you,

Yours sincerely,

(Ashish Kumar Agarwal)
AGM (Technical Services)

Encl. as above

Copy to:

1. The Member Secretary,
Central Pollution Control Board,
Email-mscb.cpcb@nic.in

2. The Member Secretary,
Madhya Pradesh Pollution Control Board,
Email- ms-mppcb@mp.gov.in

**KHARGONE SUPER THERMAL POWER PROJECT (2x660 MW)
HALF YEARLY COMPLIANCE REPORT OF
ENVIRONMENTAL CLEARANCE CONDITIONS
(For the period Oct'2025-March'2026)**

(EC Ref.-MOEFCC Letter No. J- 13012/54/2010-IA. II (T) Dated 31st March 2015)

A	MOEF and CC- Specific Conditions:	Status as on Implementation
i	Coal transportation shall be by Rail only. An additional EIA shall be carried out and an EMP shall be prepared for laying down the rail line and alternate mode of transportation, in case rail line gets delayed. The EIA/EMP shall be submitted to the Ministry within one year of issuing the EC.	Complied Rail network for NTPC-Khargone has been established and entire coal is being transported by railway route only.
ii	The Sulphur and Ash content of coal shall not exceed 0.5% and 43% respectively. In case of variation of quality at any point of time, fresh reference shall be made to the Ministry for suitable amendments in the environmental clearance.	Compliance assured MOEFCC Vide Office Memorandum dated 11.11.2020 has modified this condition. The project proponent has to only inform to the Regional Office of MOEFCC regarding the change in coal source and quality. Please refer Annexure-1 for change in coal source and quality
iii	Latest authenticated satellite imagery shall be submitted to the Regional Office of the Ministry on an annual basis to monitor the environmental alterations of the area.	Complied Satellite imagery of NTPC-Khargone and its vicinity land area is regularly submitted to the Regional Office of the MOEFCC annually. Please refer Annexure-2 for Satellite imagery for 2025 dated 23.04.2025.
iv	Vision document specifying prospective plan for the site shall be formulated and submitted to the Regional Office of the Ministry within six months.	Complied Vision document specifying prospective plan of the project was submitted to the Regional Office of the MOEFCC at Bhopal vide NTPC letter dated 07.09.2015.
v	Harnessing solar power within the premises of the plant particularly at available roof tops shall be carried out and status of implementation including actual generation of solar power shall be submitted along with half yearly monitoring report.	Complied For harnessing solar power, Roof-top and Land mounted solar power plants with total capacity of 1654 KW installed and operational within plant and township premises Actual generation of solar power during the FY 2025-26 up to Mar26 is 2155637 KWH.
vi	One twin flue stack of 275 m height shall be provided with continuous on-line monitoring system of SO _x , NO _x and *PM _{2.5} and *PM ₁₀ . Exit velocity of flue gases shall not be less than 22 m/sec. In addition to	Complied One twin-flue stack of 275 m height provided for both units. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO ₂ , NO _x and PM.

	<p>the regular parameters, Mercury emission form stack shall also be monitored of six-monthly basis.</p> <p>*As per EC Amendment letter by MOEF and CC dated 22.01.2022 the condition is modified as “PM in stack emission” in place of PM2.5 and PM10</p>	<p>Separate stacks of height 150 m also provided for FGD units of respective Unit-1 and Unit-2. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO₂, NO_x and PM at FGD Stacks. Exit velocity of flue gases being maintained above 22 m/sec in boiler attached stacks. Mercury emission form stack also being monitored periodically. Please refer Annexure-3, for Mercury emission report from stack for the reporting period.</p>
vii	<p>High Efficiency Electrostatic Precipitators (ESPs) shall be installed to ensure that particulate emission does not exceed 50 mg/Nm³. Adequate dust extraction system such as cyclones/bag filters and water spray system to control fugitive emissions in dusty areas such as in coal handling and ash handling points, transfer areas and other vulnerable dusty areas shall be provided.</p>	<p>Complied</p> <p>High Efficiency Electrostatic Precipitators (ESPs) designed for a guaranteed efficiency of 99.97 percent provided and operational. The particulate emissions are controlled and maintained within prescribed norms of 30 mg/Nm³ in compliance to MOEFCC notification dated 07.12.2015, for revised emission norms for TPPs. Adequate dust extraction system and water spray system also provided to control fugitive emissions at coal handling, coal stockyard, ash handling area, transfer points and other vulnerable dusty areas. Please refer Annexure-3, for Particulate Matter emission from stack for the reporting period.</p>
viii	<p>COC of at least 5.0 shall be adopted.</p>	<p>Compliance assured</p> <p>Closed cycle cooling water re-circulation system is implemented to meet prescribed COC, for the conservation/optimization of water requirement.</p>
ix	<p>Monitoring of surface water quantity and quality shall be conducted regularly and records shall be maintained. The monitoring points shall be located between the plant and drainage in the direction of flow of ground water and records shall be maintained. The monitored data shall be submitted to the Ministry every six months.</p>	<p>Complied</p> <p>Regular monitoring of surface water being carried out through MOEFCC accredited and NABL certified third party laboratory. Records are being maintained and monitoring reports regularly submitted to Regional Office of the MOEFCC at every six months. Please refer Annexure-3 for Surface water reports for the reporting period.</p>
x	<p>Monitoring for heavy metals in ground water in the vicinity of plant shall also be undertaken and monitoring report shall be submitted to the ministry every six months.</p>	<p>Complied</p> <p>Regular monitoring of heavy metals in ground water are being carried out through MOEFCC accredited and NABL certified third party laboratory. Monitoring reports regularly submitted to Regional Office of the MOEFCC at every six months.</p>

		Please refer Annexure-3 for Heavy metals in ground water reports for the reporting period.
xi	A well-designed rainwater harvesting system shall be put in place within six months, which shall comprise of rainwater collection from the built up and open area in the plant premises and records shall be kept for the quantity of water harvested every year and its use.	Complied Well-designed, CGWA approved rainwater harvesting system, comprise of rainwater collection from the built-up area, open area and storm water of the capacity 0.36 MCM is installed at plant premises. Records for the harvested quantity of water every year being maintained. Rainwater harvested is fully used to recharge the ground water through recharge pits as per the approved scheme.
xii	No water bodies including natural drainage system in the area shall be disturbed due to activities associated with the setting up/ operation of the power plant.	Compliance assured
xiii	Hydro geology of the area shall be reviewed annually through an institute/ organization of repute to assess impact of surface water and ground water (especially around ash dyke). In case, any deterioration is observed specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months.	Complied Baseline Hydro-geological study was carried out through National Institute of Hydrology (NIH), Roorkee. Annual review of hydro geology to assess impact of surface water and ground water (especially around ash dyke) has been also carried out through an institute/ organization of repute. Reports of surface and ground water quality are regularly submitted under hydrogeology review study report to the Regional Office of the MOEFCC at every six months. Please refer Annexure-4 for the Final Interim Report of hydrogeology review study submitted by M/s Geo-Consultancy Services for year 2025.
xiv	Wastewater generated from the plant shall be treated before discharge to comply with the standards prescribed by the SPCB/CPCB.	Complied Effluent Management Scheme implemented with the objective to treat the entire wastewater as per the prescribed statutory standards of MPPCB/CPCB. It is to be submitted that during normal course of operations, zero liquid discharge being adopted based on maximum recycle/reuse of wastewater for various plant usage.
xv	Additional soil for leveling of the proposed site, if require shall be taken from within the sites (to the extent possible) so that natural drainage system of the area is protected.	Complied For leveling of site all additional soil being taken from within the sites only (to the extent possible) with all necessary precautions to protect natural drainage system of the area.
xvi	Fly ash shall be collected in dry from and storage facility (silos) shall be provided.	Complied

	<p>Un-utilized fly ash shall be disposed-off in the ash pond in the form of slurry. Mercury and other heavy metals (As, Hg, Cr, Pb etc.) will be monitored in the effluents emanating from the ash pond and in the bottom ash also. No ash shall be disposed-off in low-lying area.</p>	<p>An ash management and disposal scheme is implemented consisting of dry ash extraction system (DAES) for dry collection of fly ash with adequate storage facility (silos) to supply ash to entrepreneurs for utilization.</p> <p>Un-utilized ash is being safely disposed in the ash pond in the form of slurry. Two different systems are being provided for ash disposal: Conventional wet slurry disposal system with ash water re-circulation for bottom ash and High Concentration Slurry Disposal (HCS D) system for fly ash disposal.</p> <p>Mercury and other heavy metals (As, Hg, Cr, Pb etc.) are regularly monitored in the ash water emanating from ash pond and in the bottom ash.</p> <p>No ash is being disposed-off in low-lying area at present. Prior permission shall be obtained for ash disposal in low-lying area.</p> <p>Please refer Annexure-3 for Mercury and Heavy metals report in ash water and bottom ash for the reporting period.</p>
xvii	<p>Fugitive emission of fly ash (dry or wet) shall be controlled such that no agricultural or non-agricultural land is affected. Damage to any land shall be mitigated and suitable compensation shall be provided in consultation with the local Panchayat.</p>	<p>Complied and Noted</p> <p>Dust suppression system comprising of water spray nozzles are provided all around the ash ponds for effective control of fugitive emission of fly ash. Additionally, localized dust suppression measures also installed inside ash pond. Further, closed trucks/bulkers/covered vehicle/closed BLC container railway wagons are being used for transportation of fly ash to avoid fugitive dust emission. Dust extraction system at coal crusher house, Dry Fog Dust Suppression at Coal transfer points, Dust suppression system at Wagon tipplers, Dust suppression water spray nozzles around the coal stock yards provided for the control of fugitive emission. Dust suppression system comprising of water spray nozzles around the ash pond provided to control the fugitive dust emissions.</p>
xviii	<p>Ash pond shall be lined with HDPE/LDPE lining or any other suitable impermeable media so that no leaching takes place at any point of time. Adequate safety measures shall also be implemented to protect the ash dyke from getting breached.</p>	<p>Complied</p> <p>To avoid any leaching and ground water contamination from ash slurry, suitable impermeable media lining provided in ash dyke. Bottom ash lagoons are lined with suitable impermeable media i.e., bentonite blended clay in order to achieve the required permeability. In HSCD lagoon the disposed</p>

		<p>layers of ash are solidified and there is very less free water. Overflow lagoon of ash dyke is also lined with impervious thick liner of 300 mm at bottom.</p> <p>The structure of ash dykes has been designed, constructed, and being operated as per state-of-the-art engineering practices for the design and construction of earth dams with adequate factor of safety. Ash dyke being constructed considering the seismic parameters in its design. Regular monitoring and inspection of ash dykes and an emergency response system will ensure that there are no risks of failure as apprehended.</p> <p>Further, in compliance to MOEFCC Gazette Notification dtd. 31.12.2021, an annual certification of ash dyke also being done as per guidelines issued by Central Pollution Control (CPCB) and Central Electricity Authority (CEA). Certification report submitted to the MOEFCC, CPCB, CEA and MPPCB.</p> <p>Please refer Annexure-11, for Ash Dyke Certification for 2025-26.</p>
xix	<p>A long-term study of radioactivity and heavy metals contents of coal to be used shall be carried out through a reputed institute and results shall be analyzed every two years and shall be reported to the Ministry along with the monitoring reports. Thereafter, mechanism for * <i>in-built continuous monitoring</i> for radioactivity and heavy metals in coal and fly ash (including bottom ash) shall be put in place.</p> <p>*As per EC Amendment letter by MOEF and CC dated 22.01.2022 the condition is modified as “<i>regular periodical monitoring</i>” in place of in-built continuous monitoring.</p>	<p>Complied</p> <p>Radioactivity content monitoring of coal and ash has been carried out annually, through Board of Radiation and Isotope Technology (BRIT) under Dept. of Atomic Energy, Govt. of India. Periodical monitoring reports of Radioactivity content in coal and ash samples are regularly submitted along with Half-yearly compliance report. Please refer Annexure-5 for Latest Radioactivity content report of coal and ash.</p> <p>Further, Regular periodical monitoring of Heavy metals content of coal has been also carried out through MOEFCC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional office of MOEFCC along with half-yearly compliance reports. Please refer Annexure-3 for Heavy metals content report for the reporting period.</p>
xx	<p>Green belt of least 50m width consisting of three tiers of plantations of native species around the plant shall be raised. Wherever 50m width is not feasible, an adequate justification shall be submitted to the Ministry and appropriate width not less than 20m shall be planted. Tree</p>	<p>Compliance assured</p> <p>Green belt development along with additional tree plantations is being carried out at all available spaces inside and outside the plant and township premises. Further tree plantation being taken up at external forest land and Govt. land to enhance the green</p>

	density shall not be less than 2500 per ha with survival rate not less than 80%.	cover. Avenue plantation along the approach roads and ash dyke also being taken up. Cumulative 5.86 lakhs tree have been planted till date at inside and outside the NTPC-Khargone premises through Govt. agencies i.e. Madhya Pradesh Rajya Van Vikas Nigam Ltd. and Rural Engineering Services dept under Govt. of Madhya Pradesh.
xxi	Green belt shall also be developed around the ash pond over and above the Green Belt around the plant boundary.	Complied Tree plantation around the ash pond, along peripheral roads has been planted and is under maintenance.
xxii	CSR schemes identified based on need-based assessment shall be implemented in consultation with the village Panchayat and the District Administration starting from the development of project itself. As part of CSR, prior identification of local employable youth the eventual employment in the project after imparting relevant training shall be also undertaken. Company shall provide separate budget for community development activities and income generation programs.	Compliance assured Need Assessment Survey (NAS) completed in Dec'2022 by M/s Grant Thornton. The total budget sanctioned for FY 2025-26 is Rs. 6.81 Cr for various CSR activities. Out of Rs. 6.81 Cr. total approved budget of CSR an amount of Rs. 2.28 Cr is utilized and activities for Balance amount is work under progress in various stages. Please refer to Annexure-6 for the list of CSR activities undertaken in during the reporting period.
xxiii	For periodic monitoring of CSR activities, a CSR Committee or a Social Audit committee or a suitable credible external agency shall be appointed. CSR activities shall also be evaluated by an independent external agency. This evaluation shall be both concurrent (every six months) and final.	Compliance assured The Social Impact Evaluation (SIE) Study has been completed in Aug23 by Indian Institute of Corporate Affairs. Please refer Annexure-7 for the copy of Social Impact Evaluation (SIE) Study.
xxiv	An Environmental Cell comprising of at least one expert in environmental science/ engineering, ecology, occupational health, and social science shall be created preferably at the project site itself and shall be headed by an officer of appropriated seniority and qualification. It shall be ensured that the Head of the cell shall directly report to the Head of the Plant who would be accountable for implementation of environmental regulations and social impact improvement/ mitigation measures.	Complied An Environment Management Group (EMG) with qualified team, headed by AGM (TS) and reporting to the Head of Plant, is already functional at the Khargone station. EMG is responsible for implementation and compliance of environmental stipulations and ensure mitigation measures.
B	MOEF and CC- General Conditions:	Status as on Implementation

i	Space for FGD shall be provided for future installation, if required.	Complied Space kept for FGD is utilized in FGD installation. FGD installation completed and available for both Units. Date of Operations (ODe) for FGD: Unit-1 and FGD: Unit-2 are 25.05.2023 and 08.12.2023 respectively.
ii	The treated effluents conforming to the prescribed standards under Environment (Protection) Act 1986 only shall be re-circulated and reused within the plant. Arrangements shall be made that effluents and storm water do not get mixed.	Complied Effluent treatment system comprising of effluent treatment plant, neutralization pit, oil and grease separator, settling ponds and cooling towers etc. provided to treat effluents conforming the prescribed standards. An integrated scheme for treatment, recycle and reuse of effluents is implemented. Cooling water blow down is reused in CHP, AHP, FGD and firefighting. Ash water effluent recirculation also being provided for reuse in ash handling purpose. Provision also made for treatment, recirculation and reuse of effluents from coal handling plant. Further, Zero Liquid Discharge (ZLD) scheme is implemented for recycle and reuse of wastewater generated, thereby reducing, and optimizing the quantities of water requirement. Independent plant effluent drainage system provided to ensure that plant effluents do not mix with storm water drainage.
iii	A sewage treatment plant shall be provided (as applicable) and the treated sewage shall be used for raising greenbelt/plantation.	Complied Sewage treatment plant (STP) provided to treat sewage effluents emanating from plant and township. The STP treated water, conforming to prescribed standards utilized for raising greenbelt/plantation.
iv	Adequate safety measures shall be provided in the plant area to check/minimize spontaneous fires in coal yard, especially during summer season. Copy of these measures with full details along with location, plant layout etc. as and when finalized, shall be submitted to the ministry as well as to the regional office of the Ministry.	Complied Adequate no. of Fire Spray and Hydrant system covering the entire power station including all the auxiliaries and buildings in the plant area is provided as per fire safety requirements. The system is adequately equipped with piping, hydrants, valves, instrumentation, hoses, nozzles, hose boxes/stations etc. Safety measures details already submitted along with Half-yearly compliance report dated 22.04.2019.

v	<p>Separate storage facilities for auxiliary liquid fuel such as LDO/HFO/LSHS shall be made in the plant area in consultation with Department of Explosives, Nagpur. Sulphur content in the liquid fuel will not exceed 0.5%. Provisions of the Manufacture, Storage and Import of Hazardous Chemical Rules and the Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996 shall be applicable as per the quantity stored. Disaster Management System shall be established as per the Disaster Management Plan to meet any eventuality in case of an accident taking place due to storage of oil.</p>	<p>Compliance assured Storage facility designed and provided for LDO as auxiliary liquid fuel, inside plant area conforming to the adequate safety standard and where risk is minimal. Necessary license has been obtained from Petroleum and Explosive Safety Organization under Ministry of Commerce and Industry. Sulphur content in LDO being ensured within limits. Detailed Disaster Management Plan (DMP) and Risk assessment including fire and explosion issues is prepared and finalized in consultation with Department of Explosives. Regular mock drills being conducted as per plan in order to address any eventuality in case of an accident.</p>
vi	<p>First Aid and sanitation arrangements shall be made for the drivers and other contract workers during construction phase.</p>	<p>Complied Adequate arrangements for first aid, health and safety, and sanitation for workers were provided during the construction phase.</p>
vii	<p>Noise levels from turbines in work zone shall be limited to 85 dB (A) from source. For people working in the high noise area, requisite personal protective equipment like earplugs/earmuffs etc. shall be provided. Workers engaged in noisy areas such as turbine area, air compressors etc. shall be periodically examined to maintain audiometric record and for treatment for any hearing loss including shifting to non-noisy/less noisy areas.</p>	<p>Complied Design specification for the equipment has been made to comply with the stipulations. Noise levels from turbines in work zone being maintained within prescribed limits of 85 dB (A) from source. Personal Protective Equipment (PPEs) are also being provided to personnel working in high noise areas. Workers of turbine generator area, compressor area and other high noise area being provided with appropriate ear protection devices. Periodic health examination of workers being done.</p>
viii	<p>Regular monitoring of ambient air ground level concentration of SO₂, NO_x, PM_{2.5} and PM₁₀ and Hg shall be carried out in the impact zone of the project and record shall be maintained. In case these levels exceed the prescribed limits, necessary control measures shall be taken immediately. The location of the monitoring stations and frequency of monitoring shall be decided in consultation with SPCB. Monitoring reports shall be submitted to the Regional Office of this Ministry every six months. The data shall also be uploaded on the website of the company.</p>	<p>Complied Three nos. of CAAQMS stations have been installed at main-plant and township locations in consultation with MPPCB for regular monitoring of ambient air quality and record is maintained. Adequate control measures have also been ensured to control the exceedance if any. Additionally, one CAAQMS station is also installed at Khargone city as per directions from MPPCB. Regular monitoring of ambient air quality also carried out periodically through MOEFCC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional Office of MOEFCC. Please refer Annexure-3 for ambient air quality reports</p>

		for the reporting period. Online ambient air monitoring data also being uploaded on NTPC-Khargone Intranet webpage.
ix	Fly Ash generated shall be utilized 100% from the 4 th year of operation of the power plant. Status of fly ash utilization shall be reported each year to the Regional Office of the Ministry.	Complied Ash utilization plan has been prepared and all efforts are being made to achieve the targets in compliance to MOEFCC, Fly ash Gazette Notification dated 03.11.2009, 31.12.2021 and its amendments, notifications thereafter. Annual compliance status of fly ash utilization being submitted regularly to the Regional office of MOEFCC. Please refer Annexure-8 for Annual compliance report (ACR) of Ash Utilization for the FY 2025-26.
x	Provision shall be made for the housing of construction labor (as applicable) within the site with all necessary infrastructures and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, crèche etc. The housing may be in the form of temporary structure to be removed after the completion of the project.	Complied Labor colony with necessary infrastructure facilities were provided for construction labor during construction phase.
xi	The project proponent shall advertise in at least two local newspapers widely circulated in the region around the project, one of which shall be in the vernacular language of the locality concerned within seven days from the date of receipt of this clearance letter, informing that the project has been accorded environmental clearance and copies of clearance letter are available with the State Pollution Control Board/Committee and may also be see at Website of the Ministry of Environment and Forests at http://envfor.nic.in .	Complied The information of Environmental Clearance was published in two newspapers widely circulated in the region are- 1. Hindustan Times (English) on dated 04.04.2015. and 2. Nai-Dunia (Hindi) on dated 04.04.2015.
xii	A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parisad/ Municipal Corporation, urban local body and the Local NGO, if any, from whom suggestions/representations, if any, received while processing the proposal. The clearance letter shall also be put on the website of the Company by the proponent.	Complied Copy of clearance letter were sent vide our letter dated 06.04.2015 to Sarpanch of village Panchayat of Selda and Dalchi village, CEO of Khargone Distt and CEO of Khargone Municipal Corporation. The Environmental Clearance is uploaded on the NTPC Ltd. website.

xiii	The proponent shall upload the status of compliance of the stipulated environmental clearance conditions, including results of monitored data on their website and shall update the same every six months. It shall simultaneously be sent to the Regional Office of MOEF, the respective Zonal Office of CPCB and the SPCB.	Complied The latest status report of Compliance to the stipulated Environmental Clearance (EC) conditions is regularly uploaded on NTPC website. Compliance status report also submitted to the Regional Office of the MOEFCC and offices of CPCB and MPPCB regularly at every six months.
v	The criteria pollutant levels namely; SPM, RSPM (PM _{2.5} and PM ₁₀), SO ₂ , NO _x (ambient levels as well as stack emissions) shall be displayed at a convenient location near the main gate of the company in the public domain.	Complied The criteria pollutant levels as prescribed, for ambient air as well as stack emissions are displayed at a convenient location near the main gate of the company in the public domain.
xv	The environment statement for each financial year ending 31 st March in Form-V as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall be submitted by the project proponent to the concerned State Pollution Control Board. The same shall also be uploaded on the website of the company along with the status of compliance of environmental clearance conditions and shall also be sent to the respective Regional Offices of the Ministry by e-mail.	Complied Environment Statement for each financial year ending 31 st March in Form-V has been regularly submitted to the M.P. Pollution Control Board and Regional Office of the MOEFCC timely by September every year. Environmental Clearance along with annual environment statement is regularly updated on the NTPC website. Please refer Annexure-9 for Annual Environment Statement (Form-V) of the FY 2025-26.
xvi	The project proponent shall submit six monthly reports on the status of the implementations of the stipulated environmental safeguards to the Ministry of Environment and Forests, its Regional Office, Central Pollution Control Board and State Pollution Control Board. The project proponent shall upload the status of compliance of the environment of the environmental clearance conditions on their website and update the same every six months and simultaneously send the same by email to the Regional office, Ministry of Environment and Forests.	Complied Six monthly compliance status report of EC conditions regularly submitted to the Regional Office of MOEFCC, CPCB and MPPCB. Reports are also uploaded on the NTPC website periodically.
xvii	Regional office of the Ministry of Environment and Forests will monitor the implementation of the stipulated conditions. A complete set of documents including Environmental Impact Assessment Report and Environment Management plan along with the	Complied A complete set of documents including Environmental Impact Assessment (EIA) Report and Environment Management Plan (EMP) along with the additional information/clarifications was already

	additional information submitted from time to time shall be forwarded to the Regional Office for their use during monitoring.	submitted to Regional Office (Western Zone) of the MOEFCC at Bhopal on 05.10.2015
xviii	The details of the funds along with item-wise break-up of Rs.1421.2 crores allocated for implementation of environmental protection measures shall be submitted to the Ministry. This cost shall be included as part of the project cost. The funds earmarked for the environment protection measures shall not be diverted for other purposes and year-wise expenditure shall be reported to the Ministry.	Compliance assured The requisite funds for environmental mitigation measures have been included in the project cost. Financial provision stipulated towards environmental mitigate measures shall not be diverted for other purposes.
xix	The project authorities shall inform the Regional Office as well as the Ministry regarding the date of financial closure and final approval of the project by the concerned authorities and the dates of start of land development work and commissioning of plant.	Complied Site leveling/ Land development work started on July 17 th , 2015. Trial operation commissioning of Unit-1 (660 MW) achieved on 29/09/2019 and Commercial Date of Operation (COD) declared from 01/02/2020. Trial operation commissioning of Unit-2 (660 MW) achieved on 24/03/2020 and Commercial Date of Operation (COD) declared from 04/04/2020.
xx	Full cooperation shall be extended to the Scientists/officers from the Ministry / Regional Office of the Ministry/ CPCB /SPCB who would be monitoring the compliance of environmental status.	Noted

COMPLIANCE REPORT OF ADDITIONAL CONDITIONS

(EC Amendment vide MOEFCC Letter Dated 22nd August 2019)

A	MOEF and CC- Specific Conditions:	Status of Implementation
1	While commissioning the proposed project, the compliance of revised emission norms vide Notification dated 07.12.2015 for the parameters PM: 30 mg/Nm ³ ; SO ₂ : 100 mg/Nm ³ ; NO _x : 100 mg/Nm ³ and Hg: 0.03 mg/Nm ³ shall be achieved along with specific water consumption as per the notification vide dated 28.06.2018. The FGD System, NO _x control measures such as SCR/ SCNR/ DeNO _x burners shall be installed to achieve the revised emission norms.	Compliance assured NTPC-Khargone ensures compliance to all standards as stipulated in the revised emission norms vide referred MOEFCC Notification dated 07.12.2015 and its amendments thereafter. Particulate Matter (PM) emissions from boiler stacks being complied within prescribed new emission norms (30 mg/Nm ³) FGD plants installed, commissioned and available for both Unit-1 and Unit-2 for SO ₂ emission being complied within prescribed new emission norms (100 mg/Nm ³)

		<p>Low NO_x burners with Over Fire Air (OFA) combustion system also provided in both Units, for NO_x emission control. However, the matter for NO_x emission compliance by TPPs commissioned after 2017 is under sub judice at Honble Supreme Court of India. As per the direction of Honble Supreme Court, a committee comprising of EPCA (CAQM), CPCB, MOEFCC and MoP is deliberating on the issue.</p> <p>Mercury emission from stacks is complied with in prescribed norms.</p> <p>Specific water consumption (SWC) being maintained within prescribed norms of 3.0 m³/MWh as per the MOEFCC notification dated 28.06.2018. SWC for FY26 is reported as 2.74 m³/MWh.</p>
2	The status of installation of FGD and De-NO _x /SCR/SNCR control systems to comply with new emission norms for both units shall be submitted.	<p>Complied</p> <p>For SO₂ emission control, installation of FGD plant package was awarded to M/s LnT for both units. Erection and Commissioning of FGD plants completed and available for both Units. Dates of Operation (ODe) for FGD: Unit-1 and FGD: Unit-2 are 25.05.2023 and 08.12.2023 respectively.</p> <p>For NO_x emission control, Low NO_x Burners with Over Fire Air (OFA) combustion control system (air/fuel ratio optimization around the burner) is provided in both units. However, the matter for NO_x emission compliance by TPPs commissioned after 2017 is under sub judice at Honble Supreme Court of India. As per the direction of Honble Supreme Court, a committee comprising of EPCA (CAQM), CPCB, MOEFCC and MoP is deliberating on the issue.</p>
3	The detailed progress report of construction of proposed project shall be submitted to the Ministry and its Regional Office along with six monthly compliance report till both units are commissioned.	<p>Complied</p> <p>Both Unit-1 and Unit-2 were commissioned and under commercial operation from 01/02/2020 and 04/04/2020 respectively.</p>
4	As per the Revised Tariff Policy notified of Ministry of Power issued vide dated 28.01.2016, project proponent shall explore the use of treated sewage water from the Sewage Treatment Plant of Municipality/ local bodies/ similar organization located within 50 km radius	Noted and Compliance assured

	of the proposed power project to minimize the water drawl from surface water bodies. The details of Sewage Treatment Plants located within 50 km radius along with the capacities shall be submitted.	
5	Daily quantity of (Average, minimum and maximum) fresh water withdrawn from Narmada River at Omkareshwar Dam for the plant purpose shall be submitted along with six monthly compliance report.	Noted and Compliance assured Please refer Annexure-10 for fresh water withdrawn data for the reporting period.
COMPLIANCE REPORT OF ADDITIONAL CONDITIONS <i>(EC Amendment vide MOEFCC Letter Dated 22nd January 2022)</i>		
A	MOEF and CC- Specific Conditions:	Status of Implementation
i	24x7 online Continuous monitoring system for ambient air quality parameters SO _x , NO _x and PM shall be established with connected server to CPCB and SPCB.	Complied Continuous Ambient Air Quality Monitoring Stations (CAAQMS) have been installed and 24x7 online connectivity of the same also established up to the MPPCB and CPCB.

Reporting Format for Change in Coal Source

Name: Khargone Super Thermal Power Project (2x660 MW), NTPC Limited

Dates of EC & Amendments: EC Ref.-J- 13012/54/2010-IA. II (T) Dated 31.03.2015,

Amendment Dtd.22.08.2019 & 22.01.2022

Compliance Reporting Period: Oct'25-Mar'26

S.No.	Description	Details of Coal Source (As per EC)	Details of Coal Source (As per FSA)	Change in Coal Source, if any
1	Coal Linkage Source (Coalfield/Coalmine)	Pakri Barwadih	For U#1- MCL For U#2- WCL/SECL	For U#1- 17.01.2023 For U#2- 06.06.2024
2	Annual Contracted Quantity (MMT)	6.5 MMT	For U#1- MCL 3.33 MMT For U#2- WCL/SECL, 2.62/2.82 MMT	
3	Distance of Coal Source from the Plant (Km)	1326 Km (Avg)	For U#1- MCL 1185 Km (Avg) For U#2- WCL/SECL, 634 Km (Avg)/896Km(Avg)	
4	Mode of Transportation (Rail/Road/Others)	Rail	Rail	
5	Total Quantity of Domestic Coal received during the period (MMT)			2.29
6	Average Coal Quality of Domestic Coal Consumed during period:-			
a)	Ash Content (%)			43.9
b)	Sulphur (%)			0.4
c)	Moisture (%)			5.33
d)	Calorific Value (kcal/kg)			3120
7	% Blending of Imported Coal, if any and Average Coal Quality of Imported Coal Consumed:-			Nil
a)	Ash Content (%)			-
b)	Sulphur (%)			-
c)	Moisture (%)			-
d)	Calorific Value (kcal/kg)			-

Note: In Case of there is no change in linkage/FSA source, column (5) may be filled as 'No Change'

Annexure-2 Latest Satellite Image

23.04.2025

NTPC Ltd, Khargone Super Thermal Power Station

The screenshot displays the LAND VIEWER interface with a satellite image of the Khargone NTPC power station area. A circular area of interest (AOI) is defined around the station. The interface includes a search bar at the top left with coordinates 22.067875, 75.854844 and an 'Upload area of interest (AOI)' button. A notification at the top center indicates '9 out of 15 free images per month' with an 'Upgrade account' button. The right sidebar shows 'PASSIVE SENSORS (DAY)' with search settings and a list of satellite images from Sentinel-2 L2A. The bottom status bar shows the current location as 'Khargone NTPC 10KM_1' with coordinates 22.06788°N 75.85485°E and a 3.0 km scale bar.

LAND VIEWER 22.067875, 75.854844

Upload area of interest (AOI)

9 out of 15 free images per month

Upgrade account

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Search settings
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23 Apr 2025

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20 Apr 2025

Sentinel-2 L2A
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43QEE

20 Apr 2025

101-120 of 2 093

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Layers

Khargone NTPC 10KM_1
22.06788°N 75.85485°E

How does EOSDA LandViewer work? ^ Terms and Conditions ^ API ^ 22.07769°N 75.67039°E 1:133 408 3.0 km

Environment Monitoring Report

Industry: NTPC Ltd. Khargone Super Thermal Power Project

Period: October'2025 to March'2026

Laboratory: M/s Hubert Enviro Care Systems Pvt. Ltd
(MOEF&CC Accredited and NABL Lab)/Online CEMS

Stack Emission Monitoring Report

For the period of Oct'25-Mar'26

Stack attached to Boiler	Parameter	PM	SO ₂	NO _x	Hg
	Unit	mg/Nm ³	mg/Nm ³	mg/Nm ³	mg/Nm ³
Unit-1	Avg	14.9	1039.0	401.0	<0.01
	Min	11.5	1028.0	394.0	<0.01
	Max	18.3	1050.0	408.0	<0.01
Unit-2	Avg	SD	SD	SD	SD
	Min	SD	SD	SD	SD
	Max	SD	SD	SD	SD

Stack attached to FGD	Parameter	PM	SO ₂	NO _x	Hg
	Unit	mg/Nm ³	mg/Nm ³	mg/Nm ³	mg/Nm ³
FGD-1: Unit-1	Avg	9.8	117.6	359.7	<0.01
	Min	7.6	9.9	356.9	<0.01
	Max	14.5	13.3	391.3	<0.01
FGD-2: Unit-2	Avg	8.3	15.5	346.0	<0.01
	Min	5.5	11.5	287.4	<0.01
	Max	13.7	23.6	388.5	<0.01

Ambient Air Monitoring Report

For the period of Oct'25-Mar'26

Location	Nr. West Boundary (AAQMS-1)				
Parameter	SO _x	NO _x	PM ₁₀	PM _{2.5}	CO
Unit	ug/m ³	ug/m ³	ug/m ³	ug/m ³	mg/m ³
Avg	9.6	22.9	50.3	22.5	0.4
Min	8.2	18.7	45.3	18.4	0.4
Max	12.4	25.8	56.1	25.4	0.5
Location	Nr. East Boundary (Gate No.3)				
Parameter	SO _x	NO _x	PM ₁₀	PM _{2.5}	CO
Unit	ug/m ³	ug/m ³	ug/m ³	ug/m ³	mg/m ³
Avg	10.5	23.5	48.2	21.6	0.4
Min	8.9	18.9	43.3	19.8	0.3
Max	15.0	25.7	54.9	25.6	0.6
Location	At Township				
Parameter	SO _x	NO _x	PM ₁₀	PM _{2.5}	CO
Unit	ug/m ³	ug/m ³	ug/m ³	ug/m ³	mg/m ³
Avg	11.7	23.4	53.3	22.1	0.4
Min	9.3	18.2	50.8	18.1	28.0
Max	12.0	26.8	52.8	22.7	0.5
Location	At Selda/Dalchi Village				
Parameter	SO _x	NO _x	PM ₁₀	PM _{2.5}	CO
Unit	ug/m ³	ug/m ³	ug/m ³	ug/m ³	mg/m ³

Avg	12.0	20.4	50.4	22.5	0.4
Min	8.1	18.5	45.3	20.3	0.3
Max	14.6	25.2	55.9	24.7	0.6

Surface Water Analysis Report					
For the period of Oct'25-Mar'26					
Parameter	Location	Vill.-Selda	Vill.-Dalchi	Vill.-Katora	Vill.-Jirbhar
PH	-	7.9	8.0	8.1	8.0
TDS	mg/L	434	394	186	664
TSS	mg/L	36.0	15	8	6
BOD	mg/L	2.0	<2	2	<2
COD	mg/L	20.0	<4	16	<4
O&G	mg/L	<4	<4	<4	<4
Chlorides	mg/L	56.9	27.2	12.4	69.3
Sulphates	mg/L	133.6	127.1	13.7	296.3
Ca	mg/L	54.1	64.1	30.1	48.6
Mg	mg/L	32.8	29.2	15.8	48.6
Cd	mg/L	<0.001	<0.001	<0.001	<0.001
As	mg/L	<0.005	<0.005	<0.005	<0.005
Hg	mg/L	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.005	<0.005	<0.005	<0.005

Ground Water Analysis Report					
For the period of Oct'25-Mar'26					
Parameter	Location	Vill.-Dalchi	Vill.-Selda	Vill.-Khedi	Vill.-Aarsi
PH	-	7.1	7.3	7.3	7.6
TDS	mg/L	1318	784	581	520
COD	mg/L	12.0	<4	<4	<4
Chlorides	mg/L	143.5	74.2	79.2	79.2
Sulphates	mg/L	416.3	378.6	63.1	56.3
Ca	mg/L	300.6	72.1	88.2	64.1
Mg	mg/L	111.8	48.6	48.6	29.2
Cd	mg/L	<0.001	<0.001	<0.001	<0.001
As	mg/L	<0.005	<0.005	<0.005	<0.005
Hg	mg/L	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.005	<0.005	<0.005	<0.005

Ash Effluent Water Analysis Report					
For the period of Oct'25-Mar'26					
Parameter	Unit	Avg	Min	Max	
PH		7.5	7.2	7.8	
TDS	mg/L	918	810	1020	
TSS	mg/L	6.2	5.0	8.0	
As	mg/L	<0.005	<0.005	<0.005	
Hg	mg/L	<0.001	<0.001	<0.001	
Cr	mg/L	<0.01	<0.01	<0.01	
Pb	mg/L	<0.005	<0.005	<0.005	
Cd	mg/L	<0.01	<0.01	<0.01	

Bottom Ash Analysis Report-Heavy Metals			
For the period of Oct'25-Mar'26			
Parameter	Unit	Result	
Pb	mg/L	<0.1	
Cr-T	mg/L	0.48	
Cu	mg/L	<0.1	
Zn	mg/L	<0.1	
Ni	mg/L	<0.1	
As	mg/L	<0.1	
Hg	mg/L	<0.1	
Cd	mg/L	<0.1	
Mg	mg/L	<0.1	
Co	mg/L	<0.1	

Coal Analysis Report-Heavy Metals			
For the period of Oct'25-Mar'26			
Parameter	Unit	Result	
Pb	mg/kg	7.2	
Cr-T	mg/kg	19.3	
Cu	mg/kg	9.9	
Zn	mg/kg	14.2	
Ni	mg/kg	8.2	
As	mg/kg	0.9	
Hg	mg/kg	<0.1	
Co	mg/kg	0.4	

FINAL INTERIM REPORT (Pre-M 2025)

**REVIEW OF HYDROGEOLOGY TO ASSESS IMPACT ON SURFACE WATER AND
GROUND REGIME AND PROPOSE SPECIFIC MITIGATION MEASURES
(ESPECIALLY AROUND ASH DYKE) AT NTPC KHARGONE (MADHYA PRADESH)**



Submitted to



**KHARGONE KHTPS
Village- Selda & Dalchi, Tehsil-Sanawad,
District – Khargone, Madhya Pradesh**

By



**GEOSCIENCE CONSULTANCY SERVICES
(A CGWA ACCREDITED & ISO 9001:2015 Organization)**

Roorkee – 247667 (UTTARAKHAND)

JANUARY-2026

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1 INTRODUCTION

1.1 Background

NTPC Limited was established in November 1975 with the mandate of planning, promoting, and organizing the integrated development of thermal power in India. Since its inception, NTPC has played a pivotal role in shaping the country's power sector. With a total installed capacity of 80,154 MW (including joint ventures and subsidiaries), NTPC operates across the nation through a diverse portfolio comprising:

- Thermal Power: 26 coal-based stations and 7 gas-based stations
- Hydropower: 1 large hydro and 1 small hydro station
- Renewables: 11 solar PV and 1 wind-based station
- Joint Venture Projects (25 total): 9 coal-based, 4 gas-based, 8 hydro, 1 small hydro, 2 wind-powered, and 1 solar PV station

NTPC contributes approximately 25% to India's total power generation. As a leader in the energy sector, NTPC is dedicated to generating reliable, efficient, and affordable power, with an ambitious target to reach 130 GW of installed capacity by 2032. The company continues to expand its energy mix, incorporating a balanced blend of fossil fuels, hydro, nuclear, and renewable sources.

1.2 Khargone Super Thermal Power Station (KHSTPS)

The Khargone Super Thermal Power Station, developed and operated by NTPC Limited, is a 1,320 MW (2 x 660 MW) coal-based power plant located near the villages of Selda and Dalchi in Sanawad tehsil, Khargone district, Madhya Pradesh. It is notable for being India's first ultra-supercritical thermal power project, utilizing cutting-edge technology to achieve an operational efficiency of 41.5%, which is higher than that of traditional supercritical units. This advanced technology significantly reduces coal consumption and carbon dioxide emissions, aligning with India's commitment to sustainable energy.





1.2.1 Fuel and Water Supply

KHSTPS requires approximately 6.6 million tons of coal per year, sourced from SECL, MCL, WCL, and NTPC's captive mines. Coal is transported via a dedicated railway network.

For its water requirements estimated at 3,700 cubic meters per hour—the plant draws water from the Omkareshwar Dam on the Narmada River, located approximately 45 km from the project site. The Government of Madhya Pradesh has allocated 40 million cubic meters of water annually for KHSTPS operations.

1.2.2 Power Allocation and Distribution

Electricity generated at Khargone is distributed across several states in India's Western Region:

- **Madhya Pradesh:** 50%
- **Maharashtra:** 16.5%
- **Gujarat:** 13.3%
- **Chhattisgarh:** 4%
- **Goa, Daman & Diu:** 0.7%
- **Unallocated (Govt. of India discretion):** 15%

1.2.3 Project Timeline and Accessibility

Construction of KHSTPS began in **July 2015**.

- **Unit 1** began commercial operations in Feb 2020
- **Unit 2** began commercial operations in April 2020

Strategically located, the plant lies 105 km from Indore and 30 km from Sanawad town. The nearest railway station is Sanawad, on the Indore–Khandwa line, and road access is available via the PWD road from Sanawad. The Devi Ahilya Bai Holkar Airport in Indore is the closest.





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1.2.4 Environmental Management and Monitoring

Recognizing the environmental implications of thermal power generation, particularly regarding water resources, NTPC has implemented proactive environmental safeguards. In 2015, NTPC commissioned a comprehensive hydro-geological baseline study by the National Institute of Hydrology (NIH), Roorkee, to evaluate the impact of construction and plant operations particularly around the ash dyke on surface and groundwater systems.

Key components of the environmental monitoring process include:

- Annual reviews in compliance with Ministry of Environment, Forest and Climate Change (MoEF&CC) conditions under the plant's Environmental Clearance (EC)
- Monitoring of heavy metal contamination and water quality
- Biannual submission of findings to the MoEF&CC regional office

To meet these obligations, NTPC issued a Letter of Intent to NIH in November 2021 for a one-year hydro-geological review and to the Indian Institute of Technology (IIT) Roorkee in the past years (2022-2024).

1.3 Recent Consultancy Engagement for Hydro-geological Assessment

In line with its environmental stewardship, NTPC issued Notice Inviting Tender (NIT) No. GEM/2024/B/5723347) on 18-12-2024 via the GEM Portal for the "Review of Hydrogeology to Assess Impact on Surface Water and Ground Regime (especially around ash dyke) and Propose Specific Mitigation Measures at NTPC Khargone."

Following a competitive bidding process, M/s. Geoscience Consultancy Services (GCS), Roorkee, Uttarakhand a CGWA-accredited organization was awarded the consultancy contract. The award was made by Sipat Project, NTPC, under Purchase Order No. 4000354142-037-1019, dated 28.02.2025 (Refer to Annexure I).

The technical terms of reference and the scope of consultancy are detailed in Section 3 of the accompanying document.

1.4 Objectives of the Consultancy Study

The primary objective of this consultancy study is to assess the hydro-geological status of the project area and the ash dyke area of NTPC Khargone, with a focus on both surface





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water and groundwater regimes. The study aims to evaluate changes over time, analyze water quality and availability, and recommend sustainable and site-specific mitigation measures.

1.4.1 Surface Water Hydrology Objectives

1. To assess any changes in the drainage pattern of the study area as compared to the previous year.
2. To evaluate the status of surface water bodies within a 10 km radius of the plant boundary, including their current usage, exploitation, and potential for the restoration of degenerated water bodies.
3. To recommend specific actions for NTPC to rehabilitate and improve the condition of degenerated surface water bodies in the study area.
4. To study the surface water quality at designated monitoring locations and identify current sources of contamination, if any.
5. To analyze the impact of post-construction activities and plant operations on surface water in comparison to the pre-construction period or the previous year.
6. To review the status of rainwater harvesting systems within NTPC premises and the current state of watershed management in the surrounding region.
7. To suggest site-specific mitigation measures for NTPC to improve surface water management and sustainability.

1.4.2 Groundwater Hydrology Objectives

1. To define the hydro-geological scenario of the study area using a water table contour map.
2. To assess the extent of groundwater depletion, if any, in the study area.
3. To estimate the annual recharge and utilization of groundwater during the operational phase of NTPC Khargone.
4. To evaluate the implementation of NTPC's rainwater harvesting policy and identify any changes in harvesting potential. To provide suggestions for enhancing groundwater recharge.





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5. To study the groundwater quality at identified locations and identify any current sources of contamination.
6. To analyze the impact of post-construction activities and operations of the thermal power plant and ash pond on groundwater resources.
7. To collect and review data from the existing groundwater monitoring network for the annual assessment of groundwater levels and quality.
8. To document the coordinates of all tube wells in the plant and township area and plot their locations on a geo-referenced map.
9. To recommend site-specific mitigation measures to address potential adverse impacts on the groundwater regime.

1.4.3 Assessment of the Soil Characteristics

To assess the impact on soil (especially around the ash dyke), depth-wise soil sampling was conducted to determine the status of its chemical composition.

1.5 Scope of Work

To achieve the objectives above, the scope of work included the following components:

- To conduct a literature review of existing hydrological and environmental data relevant to the project area.
- To perform hydrological investigations through field visits and on-site analysis.
- To design a groundwater monitoring network around the ash dyke area, aimed at detecting any leachability or contamination using isotope techniques.
- To assess surface water and groundwater quality using sampling and laboratory testing methodologies.
- To assess and review the impact on soil (especially around the ash dyke), depth-wise (topsoil, 30 cm, & 60 cm below surface) sampling of soil to determine the status of chemical composition.

All objectives stated in the Terms of Reference (ToR) shall be fulfilled in a structured manner outlined in the subsequent section of the report.





1.6 Literature Review

A comprehensive collection of documents and reports related to the study area was obtained from various authoritative agencies, including the Geological Survey of India, State Department of Geology and Mining, Central and State Water Boards, State Water Resources/Irrigation Departments, Central Water Commission, and the India Meteorological Department, among others.

The consultant conducted a detailed review of all relevant existing reports and data, with support and facilitation from NTPC. This literature review provided a foundational understanding of the region's hydrogeological and hydrological baseline conditions.

Based on the insights from this review, a comprehensive and structured study plan was developed in alignment with the scope and objectives outlined in the Terms of Reference (ToR).

1.7 Field Studies

Field investigations were conducted to comprehensively assess the surface water and groundwater regimes within the study area. These studies incorporated advanced tools, seasonal monitoring, and scientific analysis. The key components of the field study are as follows:

1. **Depth-wise Soil sampling and Analysis:** Analysis of Soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO₃, HCO₃, Cl, SO₄, NO₃, F⁻, and PO₄), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) at 16 locations at the surface, 30 cm and 60 cm depth.
2. **Drainage and Surface Water Body Mapping:** Drainage patterns and surface water bodies within the study area were identified and mapped. Satellite data were used for Land Use and Land Cover (LULC) mapping, along with delineation of water bodies. Any increase or reduction in the area covered by water bodies within the study region was documented and analyzed.





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3. **Well-Logging and Groundwater Flow Analysis:** Well logging was conducted to record water level measurements and water quality parameters. The collected data were used to determine hydraulic gradients and to analyze groundwater flow characteristics using flow net analysis in both the pre-monsoon and post-monsoon seasons.
4. **Water Quality Monitoring:** Surface and groundwater samples were collected and analyzed at 16 locations within a 10 km radius of the NTPC plant. Monitoring was conducted during both the pre-monsoon and post-monsoon seasons. The following parameters were analyzed:
 - Physicochemical Parameters: pH, TSS, DO, BOD, COD, dissolved phosphate, nitrate, ammonia, and Silica
 - Major Ions: Na⁺, K⁺, Ca²⁺, Mg²⁺, HCO₃⁻, Cl⁻, SO₄²⁻, and F⁻
 - Heavy Metals: Fe, As, Cd, Cr, Hg, Pb, Zn, Ni, Cu, Ba,
 - Sample collection and isotopic characterization of groundwater during pre- and post-monsoon seasons.





2 STUDY AREA

2.1 Overview of Khargone Super Thermal Power Station (KHSTPS)

KHSTPS is India's first ultra-supercritical coal-based thermal power project, located near Selda and Dalchi villages in Khargone district, Madhya Pradesh. Developed by NTPC Limited on an Engineering, Procurement, and Construction (EPC) basis, the project represents a major milestone in India's pursuit of high-efficiency and low-emission thermal power generation.

KHSTPS has a total installed capacity of 1,320 MW, comprising two units of 660 MW each, utilizing ultra-supercritical technology to achieve superior operational efficiency and reduced emissions compared to conventional thermal plants.

2.1.1 Project Timeline and Coal Source

- The project received Environmental Clearance (EC) in March 2015.
- Site preparation commenced in July 2015.
- Commercial operations at Unit 1 commenced in February 2020, and Unit 2 began commercial operations in April 2020.

The plant is fueled by domestic coal sourced from SECL, WCL, MCL & NTPC Captive mines.

2.1.2 Land Acquisition Details

The total land acquired for the plant facilities, ash dyke, and Township is 554.42 hectares (1370 acres), including:

- 317.19 hectares of private land
- 111.709 hectares of government land
- 8.985+4.5096 hectares of forest land





2.1.3 Water Requirement and Source

The plant meets its water requirement from the Omkareshwar Dam on the Narmada River, situated approximately 45 km from the project site. The Government of M.P. has approved an allocation of 55 cusecs of water for the project. The total estimated water requirement is approximately 3,700 cubic meters per hour.

2.1.4 Water Management System

KHSTPS is designed with a strong focus on water conservation, reuse, and effluent minimization. The following key features are integrated into the plant's water management system:

1. Re-circulating Cooling Water (C.W.) System: Equipped with cooling towers or open systems in compliance with MoEF&CC standards, ensuring minimal thermal pollution and efficient water use.
2. Reuse of Cooling Tower Blowdown: Utilized for coal dust suppression, ash handling, firefighting, and other service water needs, reducing freshwater intake.
3. Effluent Recycle and Reuse: Effluents generated from coal handling and service systems are treated and recycled back into the system.
4. Ash Water Recirculation: A closed-loop system minimizes the discharge of water from the ash handling process.
5. Filter Backwash Recirculation: Backwash water from filtration units is routed back to the clarifier inlet for treatment and reuse.

2.1.5 Effluent Management System

An integrated effluent management system has been implemented to ensure effective collection, treatment, reuse, and controlled disposal of all wastewater streams. This system significantly reduces reliance on makeup water and mitigates environmental impacts, aligning with NTPC's sustainability goals.

2.2 Location of Plant

2.2.1 Geographical Location and Accessibility

The KHSTPS is strategically located near the villages of Selda and Dalchi in the Khargone district of Madhya Pradesh, India. Geographically, the district is surrounded by:

- North: Dhar, Indore, and Dewas districts
- South: Jalgaon district of Maharashtra
- East: Khandwa and Burhanpur districts
- West: Barwani district

The project site enjoys good connectivity and is situated approximately:

- 105 km from Indore (nearest major city and airport)
- 50 km from Khargone city
- 35 km from Gogawa
- 30 km from Sanawad town



Figure 1: Landscape View of Khargone Super Thermal Power Station (KHSTPS).



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The nearest railway station is Sanawad, approximately 32 km from the project site, located on the Indore–Khandwa railway section. The closest airport is Devi Ahilya Bai Holkar Airport in Indore, about 105 km away, providing regional and national air connectivity.

2.2.2 Environmental Study Area and Key Features

The environmental assessment study area for KHSTPS extends across a 10 km radius from the periphery of the main plant, ash pond, and the township. However, to ensure a comprehensive understanding of the environmental context, significant features beyond this core radius are also considered.

One such feature is the Omkareshwar Dam, located on the Narmada River approximately 15 km north of the project site. As the primary water source for KHSTPS, this dam is critical to the plant's operations and is included in the environmental impact study.

Additionally, all notable surface and groundwater bodies located within a 10–15 km radius are assessed to evaluate their potential influence on or vulnerability to project activities. It includes hydrological, ecological, and usage assessments to support sustainable resource management.

This expanded scope ensures that both immediate and extended environmental impacts are carefully evaluated, in line with NTPC's commitment to sustainable and responsible power generation. **Figure 2** shows the geographical location of the Khargone Super Thermal Power Station (KHSTPS) and 10 km buffer zone.



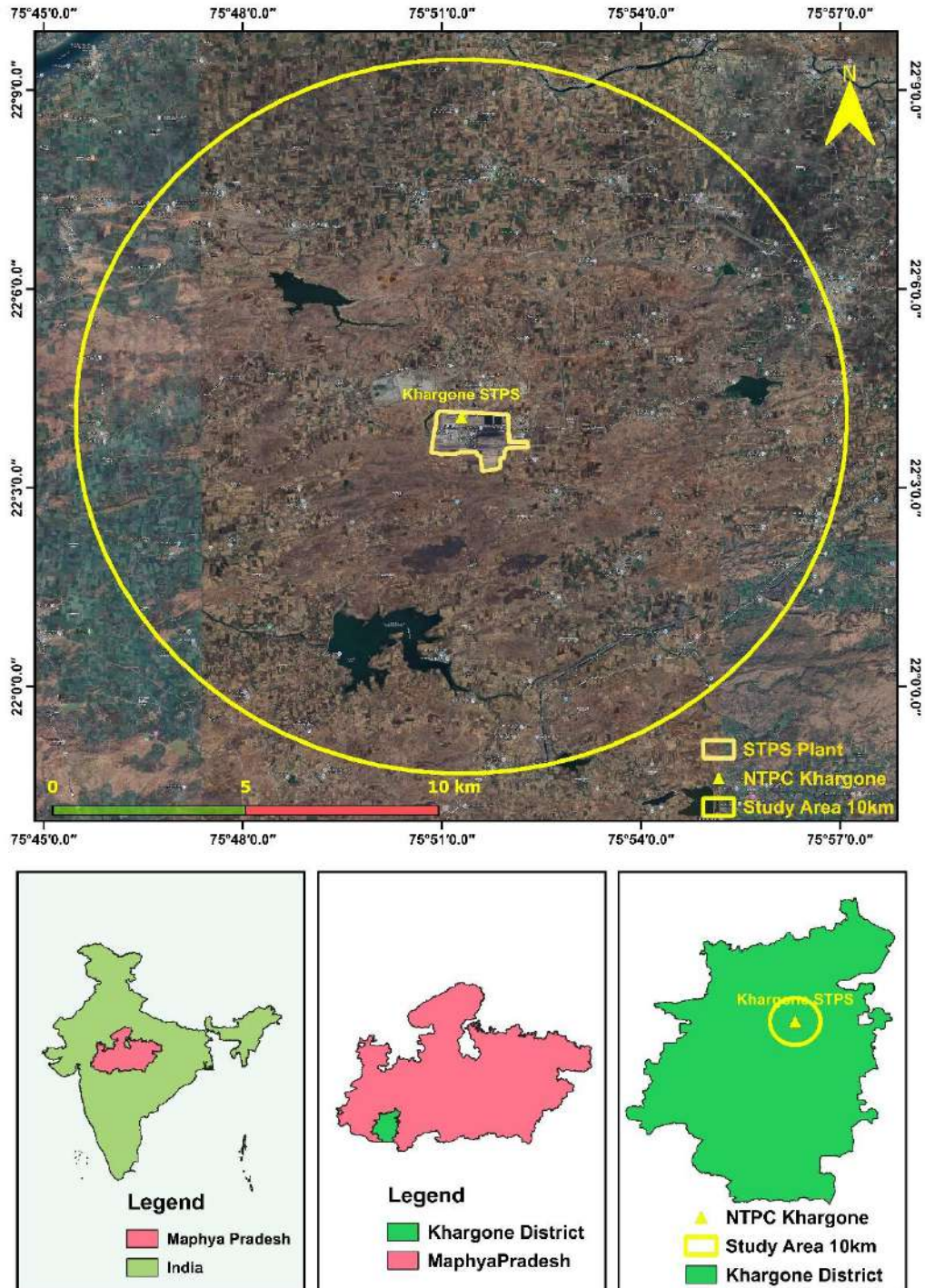


Figure 2: Location map of Khargone Super Thermal Power Station (KHSTPS). Google Earth Image 19 March 2024



2.3 Topography of the Study Area

The study area is located in the Sanawad Tehsil in the northern part of Khargone District, Madhya Pradesh, and is characterized by gently undulating terrain typical of the Deccan Plateau. Geographically, this region lies within the Narmada Valley, bounded by the Vindhya Range to the north and the Satpura Range to the south. The area is traversed by the Narmada River and its tributaries, including the Kunda and Veda rivers, which significantly shape the landscape.

Topographic analysis was conducted using Survey of India toposheets (Nos. 46O/13 and 46N/16) and high-resolution 1 arc-second Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data processed through QGIS software. The results indicate that:

- Elevation ranges from approximately 185 meters to 746 meters above mean sea level (AMSL).
- The average elevation across the study area is around 279 meters amsl
- The general slope direction is towards the northwest, with gradient values varying between 0.4 and 0.7 meters per kilometer

The topography is characterized by low hills, plateaus, and gently sloping plains, which significantly influence local drainage patterns, land use, and agricultural suitability. The moderate elevation variation supports both surface runoff and infiltration, making it conducive to irrigation projects and watershed development.

In summary, the topography of the study area embodies the distinctive features of the Deccan Plateau - a combination of gently sloping terrain, volcanic geology, and river systems - that collectively shape the region's hydrology, soil profile, and land use patterns.

2.4 Climate

The region surrounding NTPC STPS Khargone experiences a semi-arid to transitional climate, influenced by both tropical wet-dry and humid subtropical climatic patterns. The area exhibits distinct seasonal variations, characterized by temperature extremes





and a high dependence on monsoonal rainfall to maintain hydrological and agricultural sustainability.

2.4.1 Temperature Regime

The climate is characterized by hot summers, with daytime temperatures often exceeding 40°C, particularly in April and May. In contrast, the winter season is brief but cooler, with minimum temperatures occasionally dropping to around 11°C. The average annual maximum temperature is approximately 34°C, while the mean minimum temperature is around 19.6°C.

2.4.2 Rainfall and Monsoon Dynamics

Rainfall in the region exhibits a pronounced seasonal pattern, with the southwest monsoon (June–September) accounting for nearly 93% of the annual total. According to the CGWB¹, the long-term average annual rainfall is about 835 mm, although considerable year-to-year variability is observed. Over the past 30 years, the maximum rainfall of 1130.1 mm occurred in 1998, while the minimum of 330.4 mm was recorded in 2005². In 2025, the total annual rainfall measured 825.2 mm³.

This variability underscores the critical need for adaptive water resource planning that encompasses rainwater harvesting, storage optimization, and aquifer recharge strategies.

2.4.3 Humidity and Wind Patterns

Relative humidity peaks during the monsoon season, especially in August, exceeding 85%. The driest month is typically April, with relative humidity dropping to around 34%. Wind speeds also vary seasonally, with June recording the highest average speed (2.5 km/h).

¹ https://cgwb.gov.in/old_website/District_Profile/MP/Khargone.pdf

² Solanki, L. S., Kulshreshtha, V., & Rizwan, M. (2022). Rainfall Trends in Khargone Area, India: Their Effects on Hydrogeological Regimes.

³ <https://khargone.nic.in/en/notice/information-about-rainfall-in-khargone-district/>





2.4.4 Climatic Implications

These climatic parameters significantly influence:

- Evapotranspiration rates
- Groundwater recharge and water table dynamics
- Soil moisture retention and crop viability
- Ash dyke hydrology and seepage behavior, if any

Given the strong monsoonal recharge followed by extended dry periods, a well-designed groundwater monitoring system, along with rainwater harvesting structures, is essential to mitigate seasonal water stress and ensure sustainable water quality.

2.5 Physiography and Geomorphology

The Khargone Super Thermal Power Station (KHSTPS) is located within the undulating terrain of the Deccan Plateau in Khargone District, Madhya Pradesh. The site lies at elevations ranging between 227 m and 260 m above mean sea level (AMSL) within a physiographic zone predominantly composed of basaltic uplands.

2.5.1 Physiographic Setting

The region is underlain by compact to moderately porphyritic basaltic lava flows, part of the Deccan Traps, characterized by:

- Low porosity
- Moderate permeability
- Limited infiltration capacity

The general land slope trends northwest, in alignment with the regional drainage gradient, which supports surface water runoff and defines local stream courses.

2.5.2 Geomorphological Features

The site exhibits a dendritic drainage pattern, shaped by local tributaries such as the Vamsali and Ambak Rivers, which eventually drain into the Narmada River, located approximately 11.5 km to the north. Additional geomorphological features include:

- Minor lineaments and columnar jointing within basalt flows influence local drainage pathways and groundwater flow directions



- Floodplains and pediplains along the riverbanks
- A mix of medium black cotton soils and alluvial deposits in isolated patches

These features collectively govern the region's hydrogeological response, including groundwater recharge potential, runoff behavior, and aquifer dynamics.

2.6 Drainage

The drainage system in the vicinity of the KHSTPS is predominantly dendritic in nature, a characteristic indicative of the uniform basaltic lithology typical of the Deccan Plateau. This drainage pattern is shaped by the region's geological homogeneity, gentle undulations, and consistent terrain slopes.

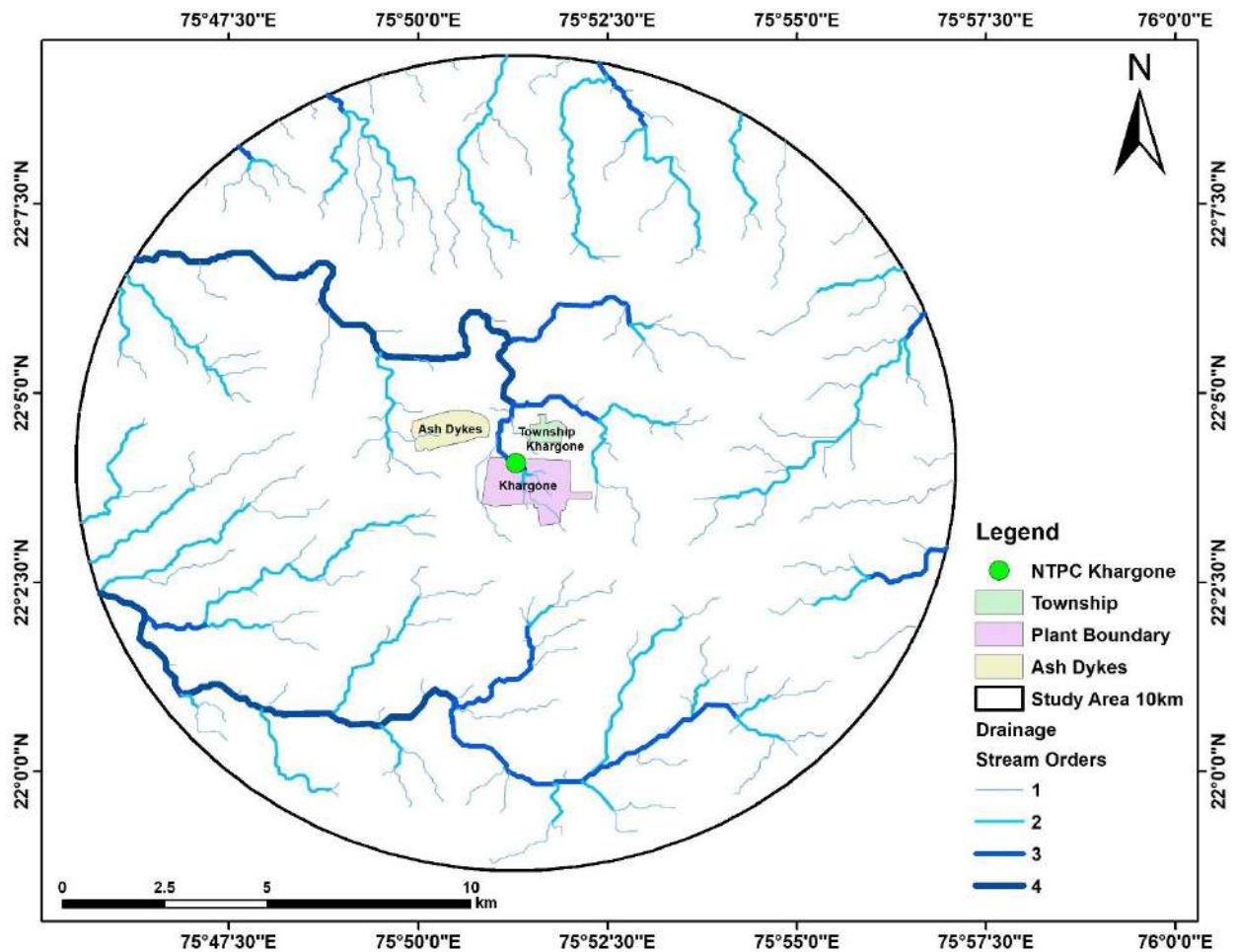


Figure 3. Drainage network around the NTPC Khargone



The Narmada River, one of India's major west-flowing rivers, is the principal drainage artery for the region. It flows approximately 11.5 kilometers north of the KHSTPS site and receives runoff from various tributaries, including two key streams:

- Vamsali River
- Ambak River

These tributaries drain the immediate surroundings of the project site and eventually discharge northward into the Narmada River, playing an important role in the local surface water regime.

2.7 Soil Characteristics

The soil profile within the NTPC Khargone project area is predominantly composed of medium black cotton soils, which are characteristic of the Deccan Plateau region.

These black cotton soils are primarily composed of approximately 50% silt and clay, rendering them moderately to highly fertile. However, their drainage capacity is variable, often leading to waterlogging during heavy rainfall and cracking during dry spells due to their expansive clay content.

The soils are typically underlain by fractured basaltic bedrock, part of the extensive Deccan Traps volcanic formation. This basaltic substructure restricts deep water percolation and influences groundwater recharge and storage behavior in the region.

In areas adjacent to the Narmada River and its tributaries, isolated alluvial soil deposits are observed. These soils are:

- Lighter in texture
- More permeable
- Generally, it is more favorable for infiltration and groundwater recharge

These alluvial pockets contrast with the heavier, black soils and are often found in riparian zones, where they support seasonal agriculture and the growth of natural vegetation.

2.8 Hydrogeology

The hydro-geological regime of the NTPC Khargone study area is predominantly controlled by the basaltic lithology of the Deccan Traps, which form the major geological





unit underlying the region. These basaltic formations consist of alternating layers of compact, massive, and fractured basalt, resulting in a heterogeneous aquifer system with variable hydraulic properties.

2.8.1 Aquifer Characteristics

Groundwater in the study area occurs primarily within the:

- Weathered basaltic zone (upper phreatic layer)
- Fractured and jointed basaltic units (semi-confined zones)

These aquifers typically exhibit:

- Low porosity and permeability, due to the dense nature of the basalt
- Localized secondary porosity, developed through fracturing and weathering
- Limited connectivity between fractured zones, affecting groundwater flow

Aquifer testing conducted near the ash dyke area revealed:

- Transmissivity (T): $\sim 6.55 \text{ m}^2/\text{day}$ (indicative of poor aquifer yield) as per CGWB
- Storage coefficient (S): $\sim 3.6 \times 10^{-2}$ (typical of semi-confined conditions)


These values confirm that the region has restricted groundwater movement and limited aquifer potential, especially in unweathered zones.

2.8.2 Groundwater Depth and Seasonal Fluctuations

Groundwater occurs at variable depths across the study area:

- Shallow depths near surface water bodies, canals, and low-lying zones due to direct recharge
- Greater depths in upland areas with less infiltration

Seasonal monitoring data reveals a significant post-monsoon rise in water levels, with increases of up to 4.83 meters, highlighting moderate to good recharge potential during the southwest monsoon season.

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3 DATA OBTAINED

To effectively conduct the hydrogeological investigation and meet the study's objectives, a comprehensive dataset is required. These datasets will support the interpretation of the hydrogeological regime, aquifer behavior, recharge conditions, and environmental impacts within the study area.

3.1 Physiographic Data / Maps

1. Topographical Map / Digital Elevation Model (DEM): A high-resolution DEM (preferably 30 m resolution or better) of the study area for slope analysis, watershed delineation, and terrain modeling.
2. Location Map: A map clearly showing the project site, surrounding villages, infrastructure, and administrative boundaries.
3. Land Use / Land Cover (LULC) Map: Satellite-based land use classification map to assess existing land utilization patterns and their influence on surface runoff and infiltration.
4. Hydrological Feature Map: Mapping of existing surface water bodies (e.g., rivers, streams, tanks, ponds) and groundwater abstraction structures (e.g., open wells, bore wells, piezometers).
5. Drainage Map: Identification and delineation of the natural drainage pattern of the region using remote sensing and GIS techniques to support runoff modeling and RWH planning.

3.2 Geological Data

1. Geological Map: Detailed geological map of the area showing rock types, structures, fault lines, and weathered/fractured zones relevant to aquifer characteristics.
2. Litholog/Subsurface Geological Logs: Borehole lithology logs, geological cross-sections, and stratigraphic profiles from existing wells or exploratory drilling within and around the study area.



3.3 Climate Data

Meteorological Records:

- Daily and monthly rainfall data for at least the past 10 years
- Temperature records (maximum, minimum, and average)

3.4 Groundwater and Surface Water Data

1. Groundwater Level Data:

- Seasonal depth-to-water level measurements from existing observation wells and piezometers, covering pre-monsoon and post-monsoon periods during the study periods.

2. Water Quality Data:

- Physico-chemical and biological parameters of groundwater and surface water at monitoring locations, including but not limited to:
 - pH, EC, TDS, DO, BOD, COD, Temperature
 - Major ions (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , CO_3^{2-} , HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , PO_4^{3-})
 - Heavy metals: (Fe, As, Cd, Cr, Hg, Pb, Zn, Ni, Cu, Ba, etc.)

These datasets will be collected, validated, and integrated into GIS and hydro-geological models to develop a comprehensive understanding of the subsurface environment and to recommend appropriate mitigation and management measures.





4 METHODOLOGY

A network of observation wells/Hand pumps and surface water bodies (Rivers, Ponds, Drains, Lagoons etc.) has been set up during the present study, based on the past hydro-geological studies conducted by various institutes (IIT Roorkee and NIH Roorkee). The monitoring network includes India Mark-II hand pumps, Bore wells, open wells, Canals, Rivers, and Ponds, as well as degraded water bodies. During this study, the sampling sites were also selected from the earlier established monitoring network. However, a few stations (bore wells and hand pumps) were found to be in a damaged or malfunctioning condition; such stations were shifted to the nearest new locations. The coordinates (Latitude, Longitude) of the sampling sites were recorded using GNSS/DGPS. The details of the observation network (sampling sites) are presented in Table 1 & Table 2 respectively, for ground water level monitoring & groundwater sampling stations and surface water sampling stations. Due care was taken to ensure that the monitoring network stations were spread over different land use patterns, thereby achieving good spatial resolution by covering a 10 km radius of the study area. The sampling locations of the groundwater samples and Surface water sampling are shown in **Figure 5** and **Figure 6** during the pre-monsoon season (May 2025). Summary of the Monitoring network/sampling source details in the 10 Km radius of the Khargone STPS NTPC plant is tabulated in **Table 3**.

To prevent precipitation of trace elements, 60 mL samples collected for trace metals were acidified with HNO_3 to $\text{pH} \approx 2$ in the field, whereas 500 mL unfiltered samples were collected for ion analysis (APHA, 2012). Physicochemical and trace metal analyses were performed following the APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2012). A brief overview of the methodology adopted to achieve the study's objectives and scope elements is provided in **Table 4**. Some physicochemical parameters were measured in situ, and the rest were analyzed in the laboratory. Trace metal measurements were conducted using advanced analytical instruments at the Department of Esc., IIT Roorkee, as detailed in **Table 5 (Figure 4)**.





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Table 1: List of Groundwater level monitoring & sampling stations in and around the study area within 10 km. buffer zone during Pre-monsoon 2025

S. No.	Code	Latitude	Longitude	Location Details	Source of Sample	Sample Status
Piezometer around the dykes						
1	KGW-9	22.0783	75.8367	Piezometer 1, Ash Dyke	Piezometer	Yes
2	KGW-10	22.0772	75.8331	Piezometer 2, Ash Dyke	Piezometer	Yes
3	KGW-11	22.0748	75.8318	Piezometer 3, Ash Dyke	Piezometer	Yes
4	KGW-12	22.0729	75.8323	Piezometer 4, Ash Dyke	Piezometer	Yes
5	KGW-13	22.0706	75.8328	Piezometer 5, Ash Dyke (Sampled nearby borewell)	Piezometer	Damage
6	KGW-14	22.0709	75.8355	Piezometer 6, Ash Dyke	Piezometer	Yes
Groundwater from localities around the power plant						
7	KGW-1	22.1249	75.8952	Opposite Primary School, Vill Baddgaon	Hand pump	Yes
8	KGW-2	22.1241	75.8952	Along Roadside Vill Baddgaon	Dugwell	Yes
9	KGW-3	22.1224	75.8425	Opp. Madhya Pradesh Gramin Bank, Vill Kanapur	Hand pump	Yes
10	KGW-4	22.1235	75.7940	In House of Shri Daya Ram, Vill Londhi (Jhirbar)	Hand pump	Yes
11	KGW-5	22.0493	75.8778	Opposite Gram Panchayat office. Vill Kheri Bujurg	Hand pump	Yes
12	KGW-6	22.0755	75.9277	Near Naag Temple Lachhora	Handpump	Yes
13	KGW-7	22.0284	75.8953	Rewa Gurjar Dharamshala, Umaria	Hand pump	Yes
14	KGW-8	22.0630	75.8526	Dug well inside the NTPC Plant	Dugwell	Yes
15	KGW-15	22.0086	75.9092	Rodhiyan Tiraha Tea Shop	Dugwell	Yes
16	KGW-16	22.0076	75.8512	Near KHR 12, Hanuman Temple, Padaliya village	Hand pump	Yes
17	KGW-17	22.1090	75.9355	Dalyakhedi	Borewell	Yes
18	KGW-18	22.1077	75.7555	Near Postoffice Pipalgaon	Handpump	Yes
19	KGW-19	22.1588	75.7617	Bhatiyon Bujurg Primary School	Handpump	Yes
20	KGW-20	22.0609	75.7653	Village Bhatyaan Khurd	Handpump	No



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Table 2: List of Surface water monitoring/sampling stations in and around the study area within 10 km. buffer zone during Pre-monsoon 2025

S. No.	Code	Latitude	Longitude	Location Details	Source of Sample	Sample Status
Surface water from localities around the power plant						
1	KSW-1	22.0705	75.8581	Pond Between NTPC Power Station & Township	Pond	Yes
2	KSW-2	22.1221	75.8428	Near Health Centre along Main road, Vill Kanapur	Pond	
3	KSW-3	22.1042	75.8123	Jirbhar lake	Lake	Yes
4	KSW-5	22.0064	75.8488	Ambak Reservoir	Lake/River	Yes
5	KSW-6	22.0755	75.9277	Lachhora Talab	Pond	Yes
6	KSW-7	22.1152	75.8661	Kattora Pond, Shelda Power station-Kattora Road	Pond	Yes
Surface water supply for the power plant						
7	KSW-4	22.2278	76.0460	Narmada River Upstream Mortakka	River	Yes
8	KSW-11	22.0674	75.8606	Raw water reservoir inside the power station	Reservoir	Yes
9	KSW-14	22.1927	75.9776	Narmada River Downstream, Toksar	River	Yes
10	KSW-15	22.0077	75.9092	Ambak River, Khargone-Sanawad road	River	Yes
11	KSW-16	22.0138	75.9028	ISP Canal Near lifting scheme	Canal	Dry
Polluted surface water (after cooling) and domestic/industrial use						
12	KSW-8	22.0732	75.8339	OFL Ash Dyke	OFL	Yes
13	KSW-9	22.0740	75.8396	Lagoon 1 Ash Dyke	Lagoon-1	Yes
14	KSW-10	22.0766	75.8332	Lagoon 2 Ash Dyke	Lagoon-2	Yes
15	KSW-12	22.0729	75.8323	Seepage from lagoon near PZ 4	Ash Dyke Seepage	Yes
16	KSW-13	22.0744	75.8509	Below the tower line on the road crossing near the power station	Drain	No





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Table 3: Summary of the Monitoring network/sampling source details in the 10 Km radius of the

Sample Source	Sample Type	Monitoring Sites (No.)	No. of Samples collected	Total No. of Samples planned during the entire study
Ash dyke	Surface Water*	4	14	~64 (As per ToR#64)
Raw Water Reservoir		1		
River/Lake/Canal		6		
Pond		5		
Hand pump/ Dug well/Tube well	Groundwater**	20	19	~72 (As per ToR#64)

*During the pre-monsoon 2025 season, 14 surface water samples (ash dyke, NTPC reservoir, river, and ponds) were collected. Sampling will continue in the subsequent three seasons in accordance with the ToR, ensuring a total of 64 surface water samples over the 2-year study period (four seasons).

**During the pre-monsoon 2025 season, 19 groundwater samples (Hand pump, dug wells, and bore wells) were collected. Sampling will continue in the subsequent three seasons in accordance with the ToR, ensuring a total of 64 groundwater samples over the 2-year study period (four seasons).

For hydrochemical interpretation, water samples were classified according to source, use, and hydro-environmental setting. Surface water samples were grouped into Industrial Surface Water (process-related waters within plant premises), Managed Surface Water (reservoirs and canals used for raw water supply), and Ambient Surface Water (rivers and village ponds representing natural and diffuse anthropogenic conditions). Groundwater samples were categorized as Piezometric Groundwater (monitoring wells installed around the ash dyke and plant area) and Ambient Groundwater (hand pumps and bore wells used for drinking and domestic purposes in surrounding villages). This classification was consistently applied to Piper trilinear diagrams to enable clear comparison of hydrochemical facies across functional zones and to distinguish



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monitoring wells from potable water sources in both surface and groundwater systems.

Table 4: Methodology vis-a-vis objective/scope of the study

S. No.	Objective/Scope	Methodology
LITERATURE REVIEW		
L1	Detailed review of documents/reports already available	All data, reports, and literature available with NTPC and other organizations, such as NIH, GSI, CWC, CGWB, IMD, State WRD, and Groundwater Department, shall be collected and reviewed for various hydrological and hydro-geological aspects.
SURFACE WATER HYDROLOGY		
S1	To study drainage pattern of the study area	Soil topographic sheets / Satellite data shall be used to prepare a drainage map of the study area. Satellite data for pre- and post-monsoon periods.
S2	Identification of surface water bodies within study area	Surface water bodies shall be identified from Satellite data. Field surveys shall be conducted to verify the ground conditions and assess the health of the water bodies. Efforts shall be made to include information on their location details, current status, exploitation, potential for development, and related factors.
S3	Review available study on surface water quality and current sources of contamination, if any	The available literature and studies will be reviewed to assess water quality and contamination of surface water sources. Water samples shall be collected and analyzed. The interrelationship between surface water quality and current sources of contamination, if any, shall be evaluated based on water quality characteristics.





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S4	To develop a plan for annual review and monitoring of surface water systems in the study area	A monitoring network shall be developed or suggested based on the potential impact on water quality of surface water systems in the ash dyke area, if any. Specific locations for monitoring, parameters to be monitored, the monitoring and assessment methodology, and the monitoring frequency will be proposed.
S5	Status for rainwater harvesting potential at NTPC premises.	The potential for rainwater harvesting will be assessed, and suggestions for augmenting groundwater recharge will be provided.
GROUNDWATER HYDROLOGY		
G1	Define the present hydro-geological scenario of the study area through a water table contour map.	Available data on groundwater levels will be collected and used to prepare a contour map. This map, along with other hydrogeological data, will be used to analyze the current hydrogeological scenario of the study area.
G2	Identify aquifers, their characteristics, and present levels of exploitation; assess groundwater depletion, if any	Aquifers will be identified based on field surveys, bore logs, and litho logs, among other data sources. The groundwater draft shall be evaluated based on the sample survey. Information/data from available reports and other literature shall be used.
G3	Review the available studies on groundwater quality and current sources of contamination, if any.	The available literature shall be reviewed, and the interrelationship between groundwater quality and current sources of contamination, if any, shall be evaluated based on water quality characteristics.
G4	To evaluate the overall impact of the Ash Dyke of power project on the groundwater systems	The impact shall be assessed based on groundwater level data, water quality assessments, and hydro-geological conditions within a 10 km radius of the KHTPS NTPC plant.





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G5	To develop a monitoring network for annual review and monitoring of groundwater levels and quality	A monitoring network will be developed /suggested based on variations in groundwater-level and water-quality data. Specific locations of the source, parameters to be monitored, the methodology for monitoring and assessment, and the frequency of monitoring shall also be specified.
FIELD STUDIES		
F1	Geological mapping of the study area, including identification of litho units.	This shall be done based on the well logs/lithology data, available reports, and satellite imagery.
F2	Well logging for water level measurements to determine hydraulic gradients and groundwater flow characteristics using flow net analysis: Pre and post-monsoon seasons	Water levels shall be measured using water level indicators. The RL of the wells shall be measured either through differential GPS or ground surveys. Water level and water quality shall be measured both in the pre- and post-monsoon seasons of each year during the study period.
F3	Monitoring of surface water, Lagoon water, and groundwater quality.	For determination of water quality, samples will be collected and analyzed using standard methods for various water quality parameters like pH, EC, DO, BOD, COD, NH ₃ , Major cations (Na, K, Ca, Mg, and Fe), major anions (CO ₃ , HCO ₃ , Cl, SO ₄ , NO ₃ , and PO ₄), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.)
F4	Assessment of Soil characteristics and impact (especially around Ash Dyke Area)	Analysis of Soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO ₃ , HCO ₃ , Cl, SO ₄ , NO ₃ , F- & PO ₄), & Heavy metals (Cd, Zn, Hg, As, Cr, Pb, etc.) at various depths.





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Table 5: Analytical methods and equipment used in the study

S. No.	Parameter	Unit	Method	Equipment
1.	pH		Electrometric	pH Meter
2.	Electrical Conductivity	$\mu\text{S}/\text{cm}$	Electrometric	Conductivity Meter
3.	Temperature	$^{\circ}\text{C}$		Digital Thermometer
4.	Total Dissolved Solids	mg/l	Gravimetric	Conductivity Meter
5.	Dissolved oxygen	mg/l	Electrometric	D.O. meter
6.	BOD	mg/l	Incubation & Titration	
7.	COD	mg/l	Absorption spectroscopy	UV-Spectrometer (HACH)
8.	Alkalinity	mg/l	Titration	-
9.	Hardness	mg/l	Titration	-
10.	Bi-Carbonate	mg/l	Titration	
11.	Calcium	mg/l	Titration	
12.	Magnesium	mg/l	Titration	
13.	Chloride	mg/l	Titration	
14.	Sodium	mg/l	Flame Emission	Flame Photometer
15.	Potassium	mg/l	Flame Emission	Flame Photometer
16.	Sulphate	mg/l	Absorption spectroscopy	UV-Spectrometer (HACH)
17.	Nitrate	mg/l	Absorption spectroscopy	
18.	Fluoride	mg/l	Absorption spectroscopy	
19.	Heavy Metals	ppb	Mass Spectrometry	ICP-MS





Figure 4: Measurement of Major ions (A – Titration) (B- Flame Photometer) and heavy metals with ICPMS (C) at the Central Facilities of IIT Roorkee.



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4.1 Chemicals and Reagents

All chemicals used for analysis were of analytical reagent grade (Merck-BDH). Standard solutions of metal ions were procured from Merck, Germany. Deionized water was used throughout the analysis. All glassware and other containers used for trace metal analysis were thoroughly cleaned by soaking in detergent, then in 10% nitric acid for 48 hours, and finally rinsed with deionised water several times prior to use. All glassware and reagents used for analysis were cleaned before use.

4.2 Analytical Methodology for Water Sample

The samples were analysed in accordance with Standard Methods for the Examination of Water and Wastewater (APHA, 2012; Jain and Bhatia, 1988). The details of analytical methods and equipment used in the study are given in Table 5. Ionic balance was calculated, and the error in the ionic balance for the majority of the samples was within 10%



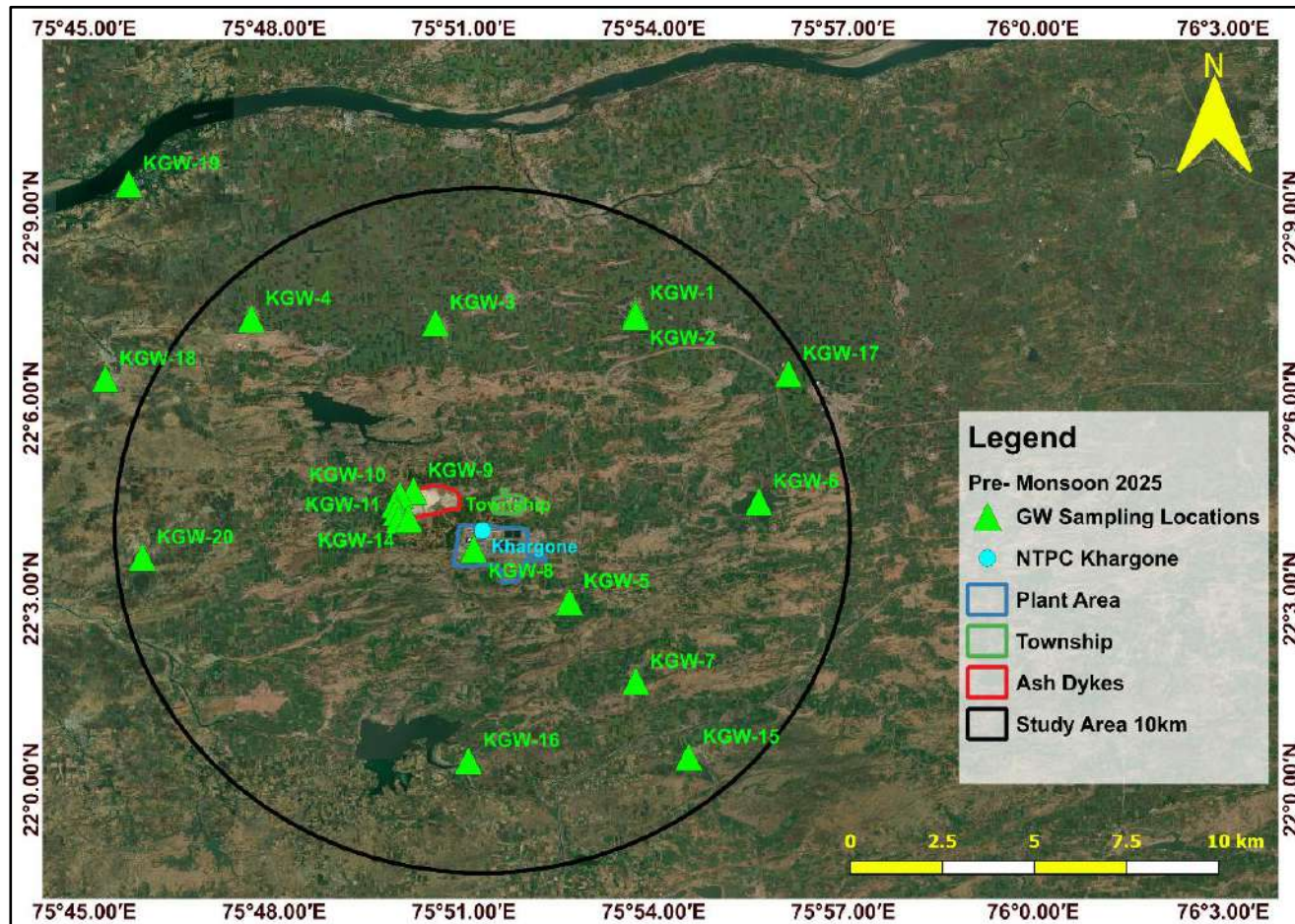


Figure 5 (a): Groundwater level monitoring and sampling locations map of Khargone Super Thermal Power Station (KHTPS), within a 10 km buffer zone of the study area during Pre-monsoon 2025.

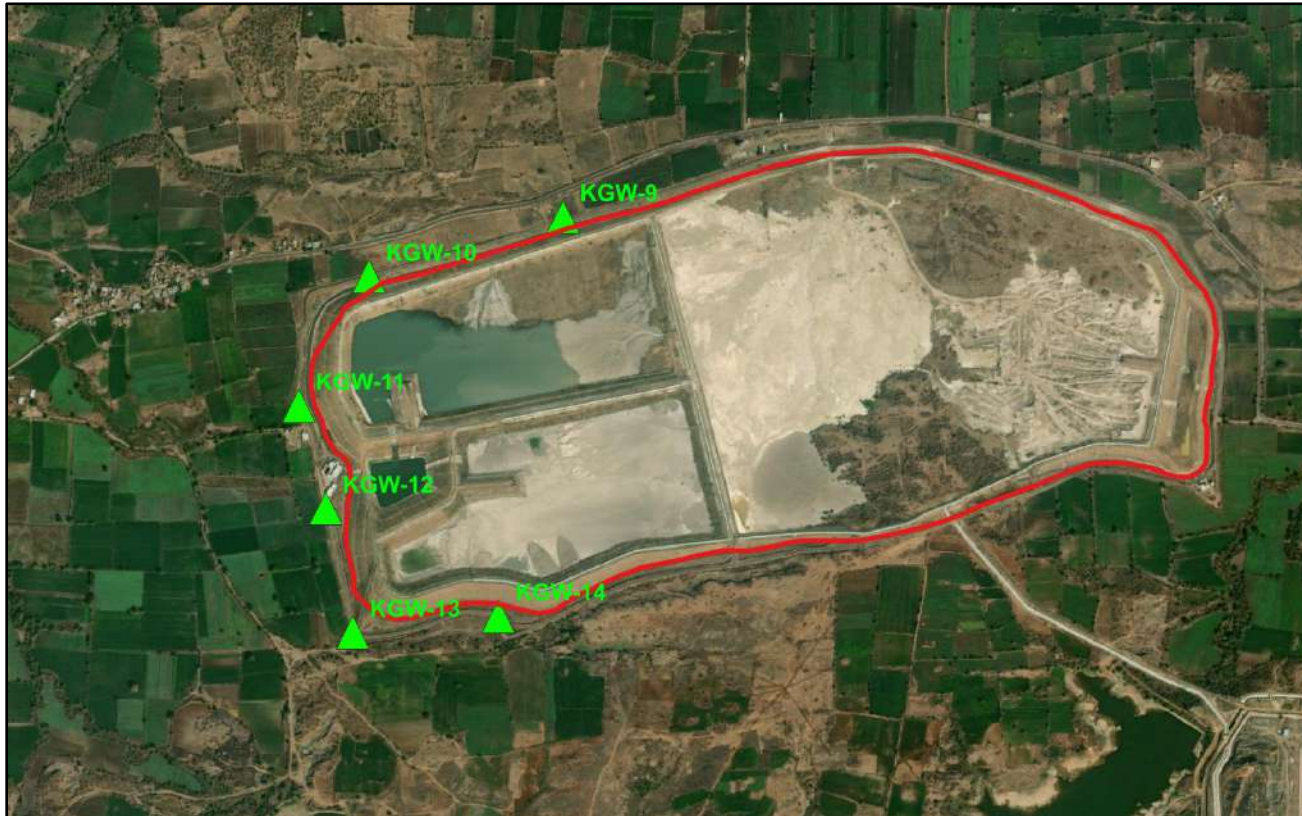


Figure 5 (b): Enlarged view of the ash dyke area showing monitoring locations in close proximity

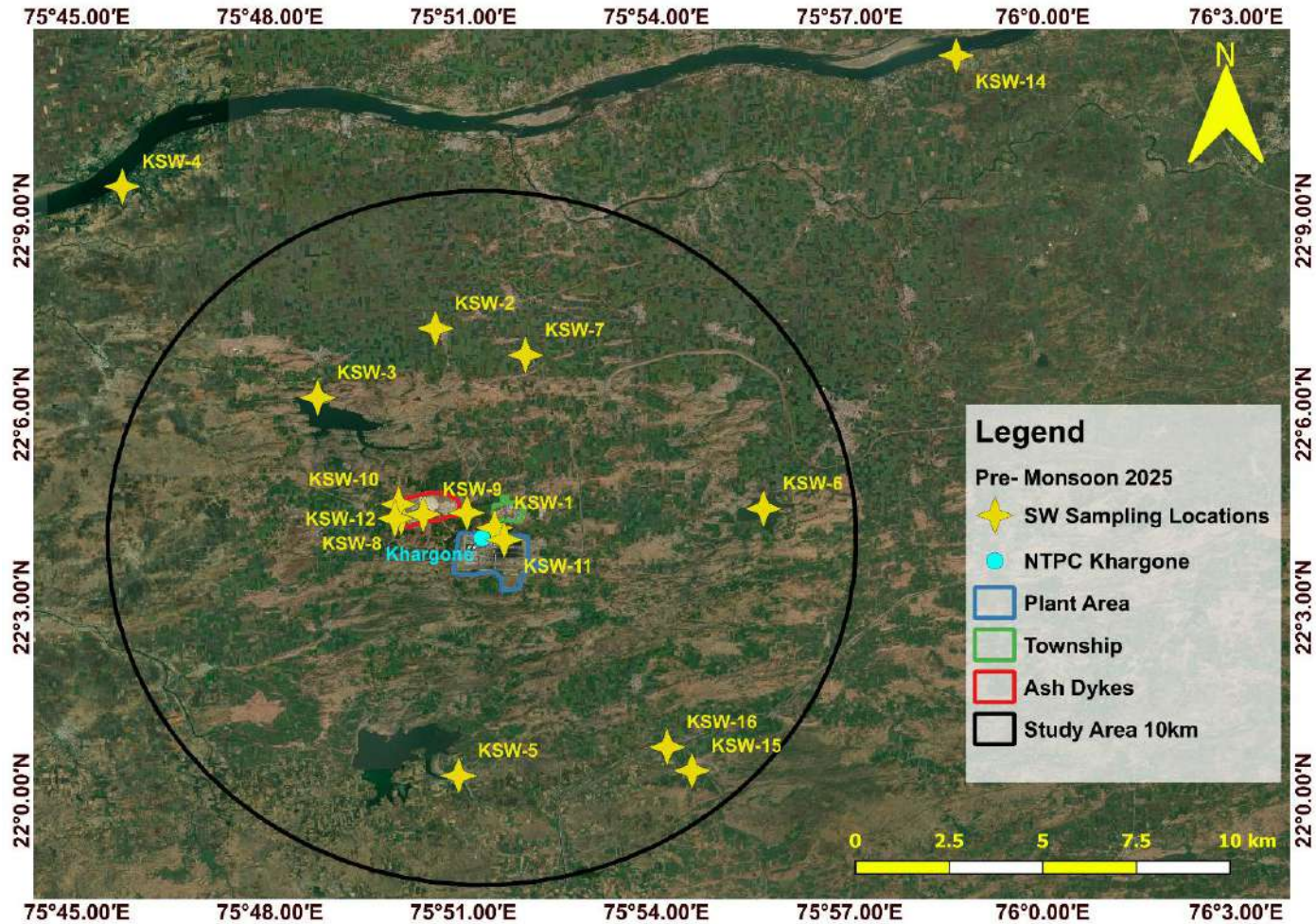


Figure 6: Surface water Sampling location map of Khargone Super Thermal Power Station (KhTPS), within a 10 km buffer zone of the study area during Pre-monsoon 2025.



Figure 6 (b): Enlarged view of the NTPC Khargone plant boundary, ash dyke area, nearby township, and surface water (SW) monitoring locations during Pre-monsoon 2025 in close proximity



5 SURFACE WATER HYDROLOGY

5.1 Background

Surface water bodies within the study area include the Narmada River, the Ambak River and its associated reservoir, an unconnected network of village ponds, and the ISP canal system, all of which play important roles in regional hydrology, water supply, irrigation, and ecological functioning. The spatial distribution of these surface water bodies and the regional drainage pattern were delineated through an integrated approach involving remote sensing interpretation, topographic map analysis, and detailed field-based reconnaissance. This combined methodology enabled accurate identification of perennial and seasonal water bodies, drainage connectivity, flow directions, and areas potentially influenced by anthropogenic activities, including thermal power plant operations.

Surface water sampling was undertaken to evaluate the hydro-chemical characteristics and water quality of representative water bodies within the study area, with particular emphasis on understanding natural geochemical controls and potential localized industrial and domestic influences. Sampling was conducted during the pre-monsoon season, a critical low-flow period characterized by reduced dilution capacity and heightened sensitivity to water-quality changes. During this period, a significant number of small ponds, minor streams, and ephemeral drainage channels were observed to be either partially or completely dry, reflecting seasonal water scarcity and the region's typical high evaporation rates.

As a result, surface water samples were collected primarily from perennial rivers, reservoirs, canals, and select ponds retaining sufficient water, ensuring that the dataset represents hydraulically active and environmentally relevant water bodies. The pre-monsoon sampling conditions provide a conservative assessment of surface water quality, as chemical concentrations during this period tend to reflect maximum solute accumulation, evaporative concentration, and operational influences, thereby allowing robust evaluation of hydro-chemical processes, compliance status, and potential environmental risk under worst-case seasonal conditions.





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Given the spatial heterogeneity of surface water bodies and their varied functional roles, a zoning-based sampling strategy was adopted to ensure representative coverage of the natural, source, and operational water regimes within the study area. Surface water sampling locations were systematically selected to capture (i) natural surface waters in surrounding localities (rivers, reservoirs, and village ponds), (ii) raw water sources used for industrial supply, and (iii) operational and potentially impacted waters associated with cooling, recirculation, and post-use industrial activities. This classification enabled differentiation between background hydro-chemical conditions and localized modifications related to anthropogenic and industrial influences.

During the pre-monsoon sampling campaign, priority was given to perennial and hydraulically connected water bodies, as many seasonal ponds and minor streams were non-functional or dry. Each selected sampling location was geo-referenced and assessed in the field for hydraulic condition, land-use influence, and proximity to industrial infrastructure. This zonation-based approach facilitated the comparative evaluation of physico-chemical and trace-metal characteristics across surface-water categories, strengthened the interpretation of Piper- and Gibbs-based hydrogeochemical controls, and ensured compliance assessment against BIS, WHO, and CPCB standards was conducted in accordance with the designated use of each water body. Consequently, the adopted sampling strategy provides a scientifically robust basis for evaluating surface water quality, identifying localized industrial signatures, and assessing environmental risk under conservative pre-monsoon conditions.

5.2 Drainage pattern of the study area

The Khargone NTPC study area lies within the Narmada River alluvial tract and its associated floodplain system, characterized by the deposition of moderately to coarse-grained alluvial sediments derived from upstream lithological units. The subsurface strata are predominantly composed of sand, gravel, and sandy loam with localized clay lenses, imparting high porosity and permeability to the aquifer system. Owing to these hydrogeological characteristics, the area exhibits limited development of well-defined





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natural surface drainage, as a substantial proportion of precipitation infiltrates into the subsurface rather than generating sustained surface runoff.

The Narmada River, the main perennial river in the area, flows mainly east-west through Khargone district within the larger study zone. It follows a structurally controlled rift valley trend and significantly influences regional drainage patterns, affecting the interaction between surface water and groundwater. Other surface water features include the Ambak River, its reservoirs, irrigation canals, and village ponds, which serve as seasonal or semi-perennial water bodies depending on monsoon recharge and controlled releases.

The overall drainage pattern of the study area is dendritic to sub-dendritic, reflecting homogeneous alluvial materials and gentle regional slopes. Minor streams and local drainage channels are largely ephemeral, remaining active only during the monsoon and early post-monsoon periods. During the pre-monsoon season, most of these smaller streams and low-lying ponds either experience significantly reduced flow or become completely dry, indicating strong seasonal control on surface water availability. This hydro-geomorphic setting promotes regular surface-groundwater interaction, high infiltration rates, and seasonal variability in surface-water extent, which are critical factors governing the hydrochemical behavior of both surface water and groundwater in the Khargone NTPC area.

5.3 Surface water bodies

A comprehensive surface water inventory, including perennial, seasonal, and degenerated or stagnant water bodies, was prepared for the Khargone NTPC study area covering a 10 km radius from the plant boundary, using high-resolution satellite imagery, Google Earth interpretation, and field validation. The analysis indicates that surface water bodies are spatially well distributed across the study area. However, their size, density, and hydrological functionality vary significantly depending on geomorphology, land use, and seasonal water availability.

Relatively larger and hydraulically active surface water bodies are concentrated in the southern and south-western parts of the study area, corresponding to the Narmada River corridor, associated floodplain zones, and irrigation command areas. These zones





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exhibit favorable geomorphic conditions for surface water retention, including low relief, alluvial deposition, and proximity to perennial river channels. In contrast, the northern and eastern parts of the study area are characterized by fewer and smaller surface water bodies, reflecting higher infiltration rates, relatively higher terrain, and reduced surface runoff.

The floodplain of the Narmada River within and adjacent to the study area exhibits distinct geomorphic features, including relict channels, abandoned meander loops, oxbow-like depressions, and palaeo-drainage traces, particularly along the south-western and north-western sectors of the buffer zone. These features represent remnants of earlier river migration and channel abandonment processes and continue to function as seasonal or stagnant water bodies, depending on monsoonal recharge and connectivity with active channels.

The south-western part of the study area shows a comparatively higher density of surface water bodies, except in localized undulating or hilly terrain, where runoff is rapid, and storage potential is limited. A significant proportion of the mapped ponds are man-made village ponds, constructed primarily for irrigation, livestock use, and domestic purposes. Many of these ponds are degraded, exhibiting shallow depths, siltation, eutrophication, and limited water retention during the pre-monsoon season. Such degenerated water bodies are particularly vulnerable to quality deterioration under low-flow conditions and therefore represent important monitoring points for assessing seasonal hydro-chemical variability and anthropogenic influence.

Overall, the spatial distribution and condition of surface water bodies within the Khargone NTPC study area reflect a strong interplay among alluvial geomorphology, seasonal hydrology, land-use practices, and human intervention, providing a critical basis for surface water quality assessment, sampling location zoning, and interpretation of hydro-chemical and trace-metal results.





5.4 Surface Water Chemical Characteristics

To evaluate the surface water quality characteristics within the NTPC Khargone study area, including a 10 km radial buffer from the plant boundary, a total of 16 surface water sampling locations were initially identified and finalized for monitoring. These locations were selected to represent a range of surface water sources, including rivers, reservoirs, irrigation canals, village ponds, and industrial/operational water bodies associated with NTPC Khargone. During the pre-monsoon dry season, several seasonal ponds and small streams were partially or fully dry. Of the 16 designated surface water sampling sites, two (KSW-2 and KSW-16) were dry and could not be sampled. As a result, 14 surface water samples were collected from active water bodies to provide a representative environmental assessment.

The collected samples represent natural surface waters (rivers, reservoirs, and ponds), raw water sources used for plant operations, and operational/industrial waters influenced by cooling and ash management systems. The pre-monsoon sampling period provides a conservative assessment of surface water quality, as reduced dilution, increased evaporation, and prolonged water–solid interaction during this season tend to accentuate chemical concentrations. Based on the analytical results obtained from these surface water samples, the physico-chemical and trace-metal characteristics of rivers, ponds, canals, and industrial water bodies within the NTPC Khargone study area are discussed in detail in the following sections, as in Table 6.





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Table 6: Physico-chemical parameters and Major ions in the buffer area during Pre-Monsoon 2025

S. ID	pH	EC	Temp	TDS	DO	BOD	COD	Na	K	Ca	Mg	CO ₃	HCO ₃	F	Cl	SO ₄	NO ₃	PO ₄
KSW-1	8.3	1146	28.6	790	3.9	16	63	48.2	3.7	64.8	33.5	ND	292	0.55	80	145.4	12.5	0.00
KSW-2	Dry																	
KSW-3	7.9	798	29.9	580	3.4	8.0	38	43.1	3.1	43.0	27.8	ND	287	0.44	40.5	81	4.2	0.00
KSW-4	8.4	303	29.3	220	6.5	7.0	36	25.3	5.2	44.7	39.7	3.9	275	0.36	59	44	3.0	0.00
KSW-5	8.1	454	27.5	330	4.0	10	40	18.6	2.4	37.3	23.7	ND	190	0.24	33.2	15	4.2	0.04
KSW-6	8.6	413	24.5	300	7.2	11	64	49.5	3.1	45.0	24.9	4.5	260	0.37	39	31.7	4.9	0.01
KSW-7	8.1	316	27.6	230	6.2	8.2	57	42.5	2.1	42.8	28.8	ND	254	0.40	65.3	62.5	13.5	0.00
KSW-8	8.2	1293	28.6	940	5.4	13	59	46.3	10.9	64.8	32.9	ND	130	2.17	81.0	264	2.2	0.00
KSW-9	6.8	1694	30.7	1210	5.2	11	73	49.2	10.3	81.6	41.7	ND	125	2.90	84.1	330	0.0	0.00
KSW-10	8.1	976	27.3	710	5.0	15	97	51.2	11.9	44.3	27.7	ND	138	2.70	73	274	1.4	0.00
KSW-11	8.2	275	30.9	200	5.7	8.5	32	25.3	4.7	74.4	32.8	ND	325	1.25	35.8	153	1.6	0.00
KSW-12	7.9	1870	28.2	1385	4.8	6.4	27	37.3	3.7	52.3	28.3	ND	182	0.65	90	78.2	10.5	0.00
KSW-13	8.3	1074	27.6	760	3.9	21	82	27.3	4.1	37.6	21.7	ND	198	0.33	57	39	0.5	0.00
KSW-14	8.9	289	29.2	210	4.0	--	--	24.3	4.2	43.8	25.4	4.6	267	0.29	20.8	25	6.0	0.04
KSW-15	8.4	610	25.6	450	4.2	14	53	30.4	2.6	33.5	17.2	ND	195	0.68	24	19.5	4.8	0.00
KSW-16	Dry																	





5.4.1 pH, Electrical Conductivity (EC), and TDS

The results of the physicochemical analysis of surface water samples collected during the pre-monsoon season are presented in **Table 6** and graphically illustrated in **Figure 7**. The pH of the analysed surface water samples within the NTPC Khargone study area varies from 6.8 (KSW-9; industrial/cooling water) to 8.9 (KSW-14; raw water source) during the pre-monsoon period. The majority of surface water samples, including those from rivers, reservoirs, canals, and village ponds, exhibit neutral to mildly alkaline character, reflecting bicarbonate buffering, carbonate dissolution, and limited acid-generating inputs. All observed pH values remain within the acceptable limits prescribed by BIS (2012), WHO (2011), and CPCB guidelines for inland surface waters and water intended for abstraction after conventional treatment, indicating no pH-related restriction on designated water uses during the pre-monsoon season.

EC of the analysed surface water samples shows considerable spatial variability, ranging from 275 $\mu\text{S}/\text{cm}$ (KSW-11; raw water source) to 1870 $\mu\text{S}/\text{cm}$ (KSW-12; industrial/impacted surface water) during the pre-monsoon period. Natural surface waters and raw water sources generally exhibit low to moderate EC values (275–610 $\mu\text{S}/\text{cm}$), whereas industrial and operational waters exhibit relatively higher EC values due to evaporation concentration, recirculation, and ash–water interactions. The average EC value across all surface water samples is approximately 825 $\mu\text{S}/\text{cm}$. Although BIS does not prescribe a specific guideline value for EC, the observed range is consistent with freshwater to moderately mineralized surface waters. It supports the zonation-based interpretation adopted for this study.

TDS concentrations in surface water samples during the pre-monsoon season range from 200 mg/L (KSW-11; raw water source) to 1685 mg/L (KSW-12; industrial/impacted water), with an overall average of approximately 720 mg/L. Among the analyzed samples, 42.9% fall within the desirable TDS limit (<500 mg/L), while 57.1% lie in the 500–1000 mg/L range, indicating overall freshwater conditions with moderate mineralization. Based on TDS classification criteria, the majority of natural surface waters and raw water sources fall within the freshwater category (<1000 mg/L), while a few industrial/operational waters exhibit higher TDS values due to operational





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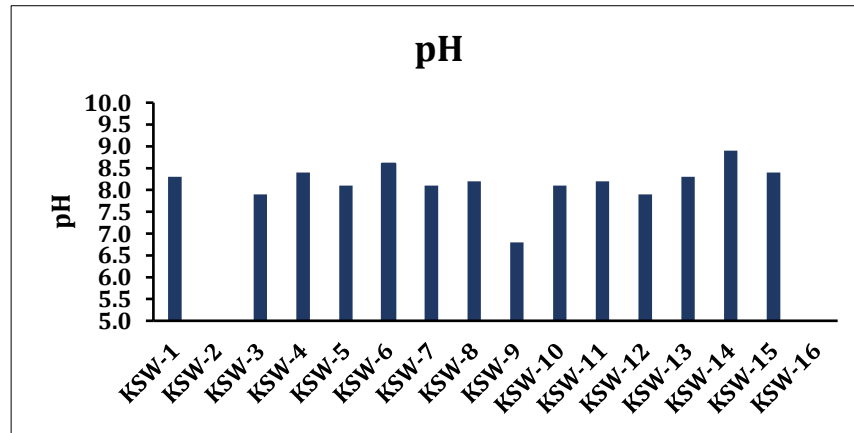
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reuse and concentration effects. These higher TDS values are not relevant to potable use, as such waters are managed within industrial systems under controlled conditions. Overall, the TDS distribution confirms that natural surface waters within the NTPC Khargone study area retain freshwater characteristics during the pre-monsoon season, while elevated TDS values are spatially restricted to operational water bodies.

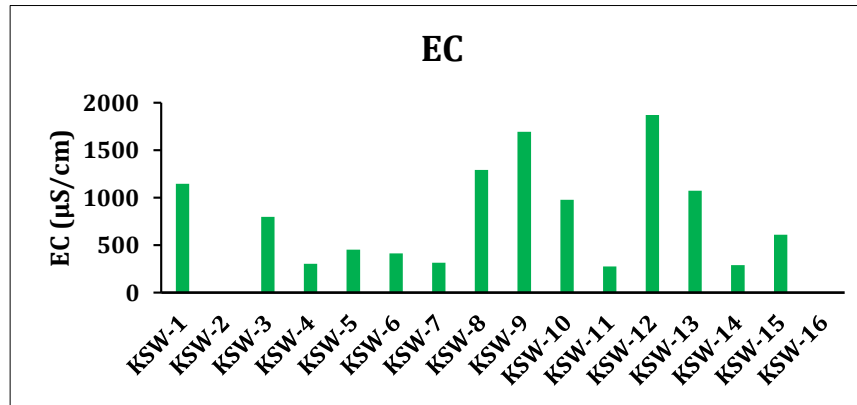
Table 7: Classification of water based on Total Dissolved Solids, (BIS-USGS Salinity Classification Framework)

TDS (mg/L)	USGS Class	BIS Drinking-Water Status	% Samples (Pre-monsoon)	Hydrogeochemical Interpretation
< 500	Fresh water	Desirable	42.9%	Recharge-dominated, low mineralization.
500 – 1,000	Fresh water	Acceptable/ Permissible	57.1%	Mild mineralization due to water-rock interaction.
1,000 – 2,000	Brackish transition	Permissible limit (only if no alternate source)	Nil	Beginning of salinity build-up.
2,000 – 10,000	Brackish water	Not suitable for drinking	Nil	Evaporation, anthropogenic input, or long residence time.
10,000 – 100,000	Saline water	Unsuitable	Nil	Strong salinization or industrial influence.
> 100,000	Brine	Unsuitable	Nil	Extreme salinity conditions.

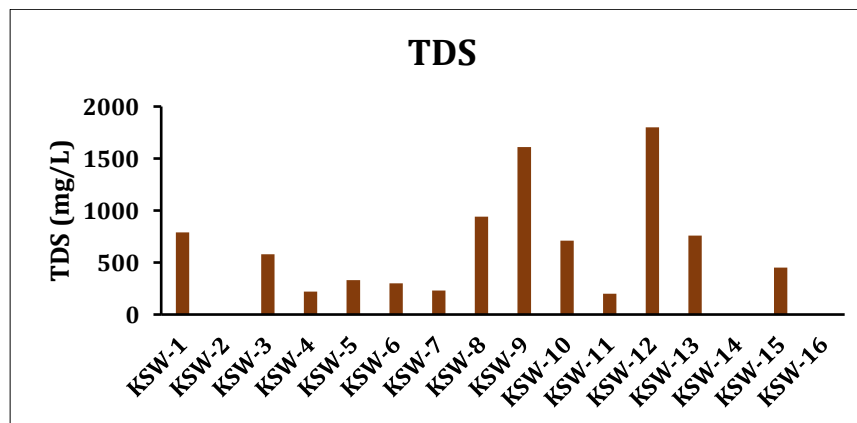




(a)



(b)



(c)

Figure 7: Pre-monsoon Graphical Representation of Physico-chemical parameters (a) pH (b) EC (c) TDS, in surface water samples in the study area.



5.4.2 Dissolved Oxygen (DO)

DO represents the concentration of dissolved molecular oxygen (O_2) in water and is a key indicator of surface water health, ecological integrity, and self-purification capacity. Oxygen enters surface water bodies primarily through atmospheric diffusion, turbulent mixing associated with flowing water, and photosynthetic activity of aquatic plants and algae. The DO concentration is influenced by several factors, including water temperature, flow velocity, depth, organic load, and biological activity; higher temperatures and stagnant conditions generally result in lower DO levels.

From an ecological perspective, DO concentrations below 5.0 mg/L can induce stress in aquatic organisms, while prolonged exposure to concentrations below ~2.0 mg/L may lead to hypoxic conditions and fish mortality. Consequently, DO is widely used as a regulatory parameter for assessing the suitability of surface waters for aquatic life propagation and designated beneficial uses.

In the NTPC Khargone study area, dissolved oxygen concentrations in surface water bodies during the pre-monsoon season range from 3.4 mg/L (KSW-3; natural surface water) to 7.2 mg/L (KSW-6; natural pond), as presented in Table 6 and Figure 8. Natural surface waters and raw water sources generally exhibit moderate to good DO levels (approximately 4.0–7.2 mg/L), indicating adequate aeration and limited organic stress. Slightly lower DO values observed at select locations reflect seasonal stagnation, elevated temperatures, and moderate organic load, typical of pre-monsoon conditions. Importantly, most surface water samples meet or closely approach the minimum DO criterion of 4 mg/L prescribed under BIS Class-C surface water standards, supporting their suitability for drinking after conventional treatment and aquatic life propagation. Industrial and operational waters exhibit marginally lower DO values in some cases due to recirculation and thermal effects, but remain within acceptable limits for controlled industrial systems. Overall, the dissolved oxygen regime of surface waters in the NTPC Khargone study area indicates no widespread oxygen depletion or ecological stress, and is consistent with the observed physico-chemical and organic load characteristics during the pre-monsoon period.



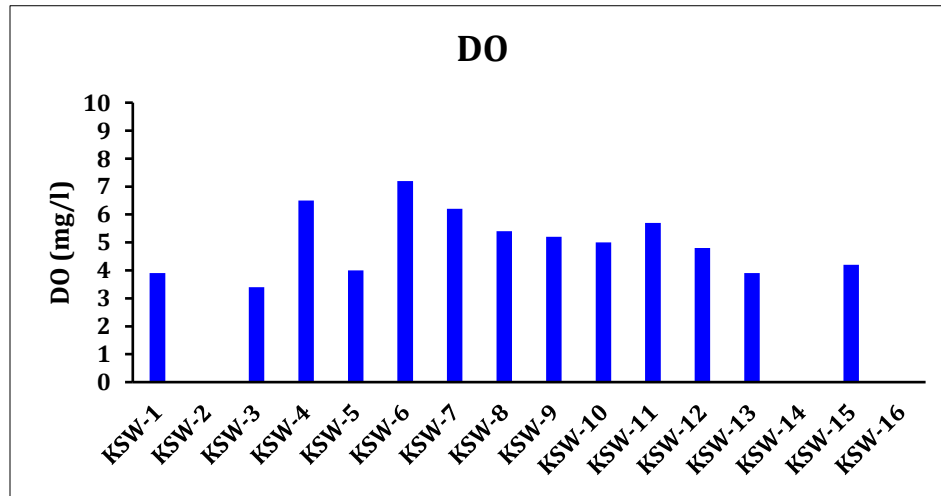


Figure 8: Dissolved oxygen (DO; mg/L) levels in surface-water samples collected from monitoring locations in the study area (pre-monsoon season)

5.4.3 Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

BOD is a measure of the amount of dissolved oxygen required by aerobic microorganisms for the biological decomposition of organic matter present in surface water bodies such as rivers, ponds, reservoirs, and canals. Several environmental factors, including water temperature, pH, flow conditions, microbial population, and the nature and concentration of organic and inorganic substances present in the water, influence the rate of oxygen consumption. In the present study, BOD was determined using the standard 5-day incubation period at 27°C, as prescribed under Indian regulatory protocols. BOD is a critical parameter governing dissolved oxygen dynamics, as higher BOD levels accelerate oxygen depletion, thereby exerting stress on aquatic organisms. Under pristine conditions, surface waters typically exhibit very low BOD values (<1 mg/L), whereas elevated BOD indicates increased organic loading from natural or anthropogenic sources.

In the NTPC Khargone study area, BOD values in surface water bodies during the pre-monsoon season range from 6.4 mg/L (KSW-12; industrial/impacted water) to 20.6 mg/L (KSW-13; industrial/operational water), as presented in Table 6 and Figure 9, with an average BOD concentration of approximately 12–13 mg/L across all sampled



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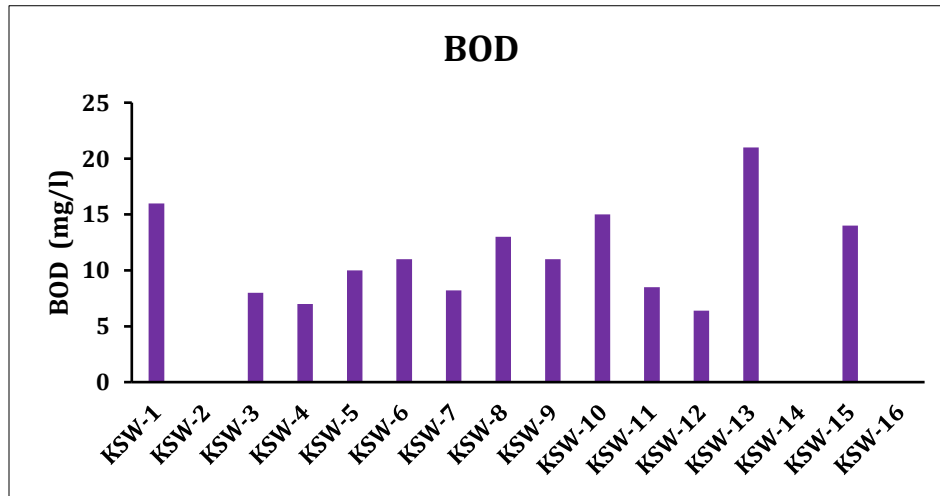
locations. Natural surface waters and raw water sources generally show moderate BOD levels, reflecting background organic matter and limited domestic inputs under low-flow conditions. Relatively higher BOD values are consistently observed in industrial and operational surface waters, attributable to recirculation, thermal effects, and accumulation of biodegradable organic matter, rather than uncontrolled discharge. Importantly, all recorded BOD values remain well within the CPCB-prescribed limit of 30 mg/L for the discharge of treated effluent into inland surface waters under the Environment (Protection) Rules, 1986, indicating regulatory compliance.

COD, which represents the total oxygen required to oxidize biodegradable and non-biodegradable organic matter chemically, as well as certain inorganic compounds, provides a complementary measure of the overall organic pollution load. Unlike BOD, COD accounts for substances that are not biologically degradable and is therefore widely used to assess the characteristics of industrial and mixed wastewater. In the NTPC Khargone study area, COD values in surface water samples during the pre-monsoon season range from 24 mg/L (KSW-14; raw water source) to 97 mg/L (KSW-10; industrial/impacted water), with higher values primarily associated with operational waters influenced by cooling and reuse cycles.

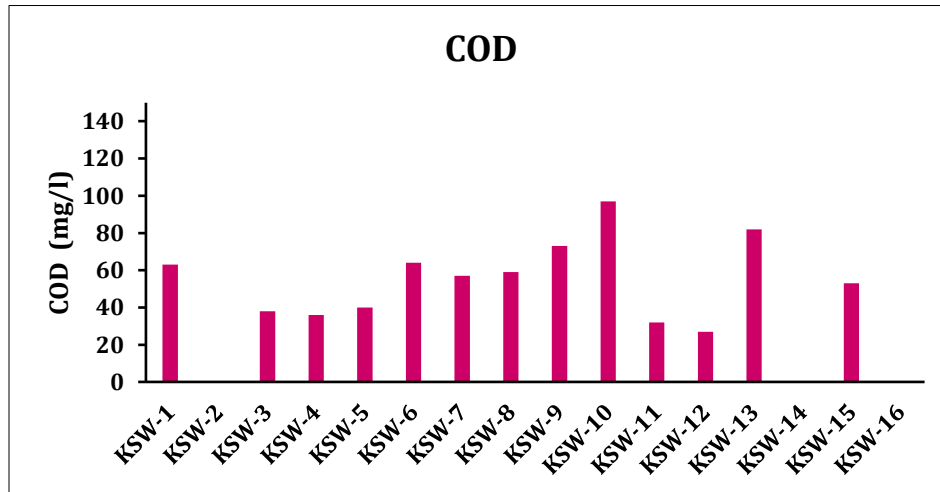
Despite this variability, all COD values are substantially below the CPCB permissible limit of 250 mg/L for discharge into inland surface waters or for land application. Furthermore, NTPC Khargone follows a zero-liquid-discharge (ZLD) and controlled recirculation system, and no untreated effluent is discharged outside the plant premises. Consequently, the observed BOD and COD levels reflect localized, managed operational conditions rather than environmental degradation, and do not pose any adverse risk to downstream surface water bodies.

Overall, the BOD–COD characteristics of surface waters in the NTPC Khargone study area indicate moderate organic loading under pre-monsoon low-flow conditions, with clear zonal differentiation between natural, source, and industrial waters, and full compliance with applicable CPCB regulatory standards.





(a)



(b)

Figure 9: (a) BOD and (b) COD levels in surface-water samples collected from monitoring locations in the study area (pre-monsoon season)

The observed DO regime in surface waters is closely linked to the spatial distribution of BOD and COD within the NTPC Khargone study area. Surface water bodies exhibiting moderate BOD and COD levels, particularly in natural and raw water source zones, generally maintain adequate DO concentrations (≥ 4 mg/L), indicating effective atmospheric reaeration, photosynthetic oxygen production, and limited organic stress. These conditions are characteristic of bicarbonate-dominated, low-chloride freshwater systems operating under seasonal low-flow conditions.



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In contrast, industrial and operational surface waters display relatively higher BOD and COD values, which correspond with slightly reduced DO concentrations at select locations. This inverse relationship reflects increased oxygen consumption associated with biodegradable organic matter, thermal effects, and recirculation processes, rather than uncontrolled organic pollution. Importantly, despite elevated BOD and COD in these waters, DO concentrations do not fall to hypoxic levels (<2 mg/L), demonstrating that oxygen depletion remains localized, transient, and well managed within the operational system.

The persistence of DO values near or above regulatory thresholds, even in waters with higher BOD and COD, highlights the role of controlled hydraulic conditions, periodic mixing, and operational management practices, including zero-liquid-discharge (ZLD) and reuse systems, in preventing sustained oxygen stress. Furthermore, the absence of severe DO depletion in natural surface waters downstream of industrial zones confirms that oxygen-demanding loads are not propagating beyond plant boundaries.

Overall, the integrated analysis of DO, BOD, and COD demonstrates a balanced oxygen budget across surface water bodies, with natural systems retaining sufficient assimilative capacity and industrial waters exhibiting controlled organic loading without ecological impairment. This coherence between DO levels and oxygen-demand parameters reinforces the conclusion that surface water quality in the NTPC Khargone area remains ecologically stable and compliant with CPCB and BIS criteria under pre-monsoon conditions.

5.4.4 Major Cations (Ca^{2+} , Mg^{2+} , Na^+ , and K^+)

The major dissolved cations in surface water within the NTPC Khargone study area comprise calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+), which collectively govern water hardness, alkalinity, and overall ionic strength. Evaluation of the updated pre-monsoon dataset indicates that calcium and sodium are the dominant cations, together accounting for a substantial proportion of the total cationic charge balance (TZ^+) in most surface water samples. This dominance reflects the combined influence of carbonate dissolution, silicate weathering, and water-sediment interaction, with localized modification under industrial and operational settings.





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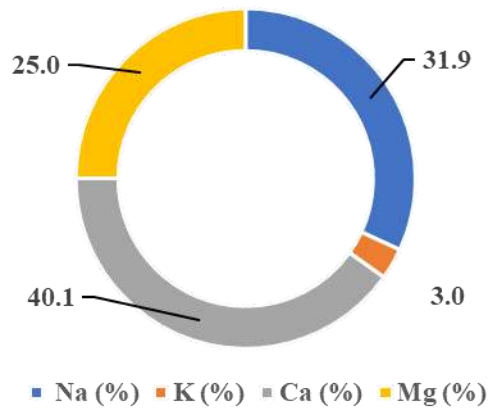
Spatial analysis of cation chemistry reveals considerable variability among natural surface waters, raw water sources, and industrial/operational waters during the pre-monsoon season. Natural surface waters and raw water supply sources are generally characterized by a mixed Ca^{2+} - Na^+ dominance, followed by magnesium and potassium, indicating geogenic control under bicarbonate-rich conditions. In contrast, surface-water samples collected from industrially influenced locations—specifically KSW-8 (OFL Ask Dyke), KSW-9 and KSW-10 (Lagoon 1 Ash Dyke and Lagoon 2 Ash Dyke), and KSW-12 (Seepage from Lagoon) —show comparatively elevated concentrations of calcium and sodium.

Comparative analysis of water quality across piezometer groundwater, open wells, and surface-water locations demonstrates that elevated calcium, sodium, and sulphate concentrations are spatially restricted to samples associated with the cooling-water dyke, seepage lagoon, and ash-handling zones. The ionic composition, enrichment patterns, and evaporation-driven concentration trends are consistent with documented fly-ash seepage and industrial recirculation chemistry, whereas they are absent from background groundwater. These multiple lines of evidence collectively indicate that the observed hydrochemical alterations are primarily attributable to industry-related activities rather than natural geogenic processes.

Overall, the cationic abundance pattern for surface waters during the pre-monsoon season can be broadly expressed as $\text{Ca}^{2+} \approx \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ for natural and source waters, while industrial and operational waters tend to show enhanced Ca^{2+} dominance, followed by Na^+ , Mg^{2+} , and K^+ . The consistently lower potassium contribution across all zones reflects its limited mobility in natural waters, owing to its fixation in clay minerals and the resistance of K-bearing silicates to rapid weathering Figure 10.



Cationic Abundance in River/Pond Water



Cationic Abundance in Lagoon/Ash Pond Water

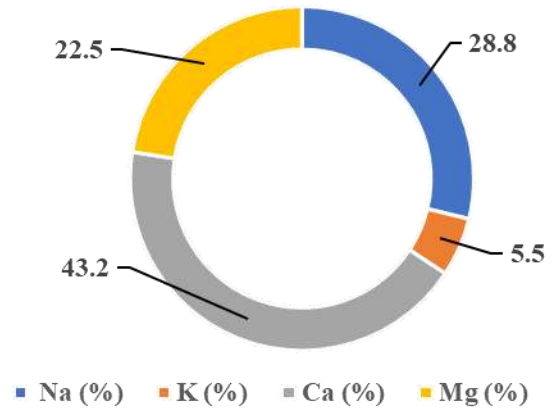


Figure 10: Cationic abundance in groundwater samples, showing the relative contribution (%) of Na⁺, K⁺, Ca²⁺, and Mg

The observed cationic composition and its spatial variation are consistent with interpretations of the Piper and Gibbs diagrams, confirming that surface water chemistry in the NTPC Khargone area is primarily governed by rock–water interactions and localized operational influences, without evidence of saline intrusion or anthropogenic sodium–chloride-type contamination during the pre-monsoon period.

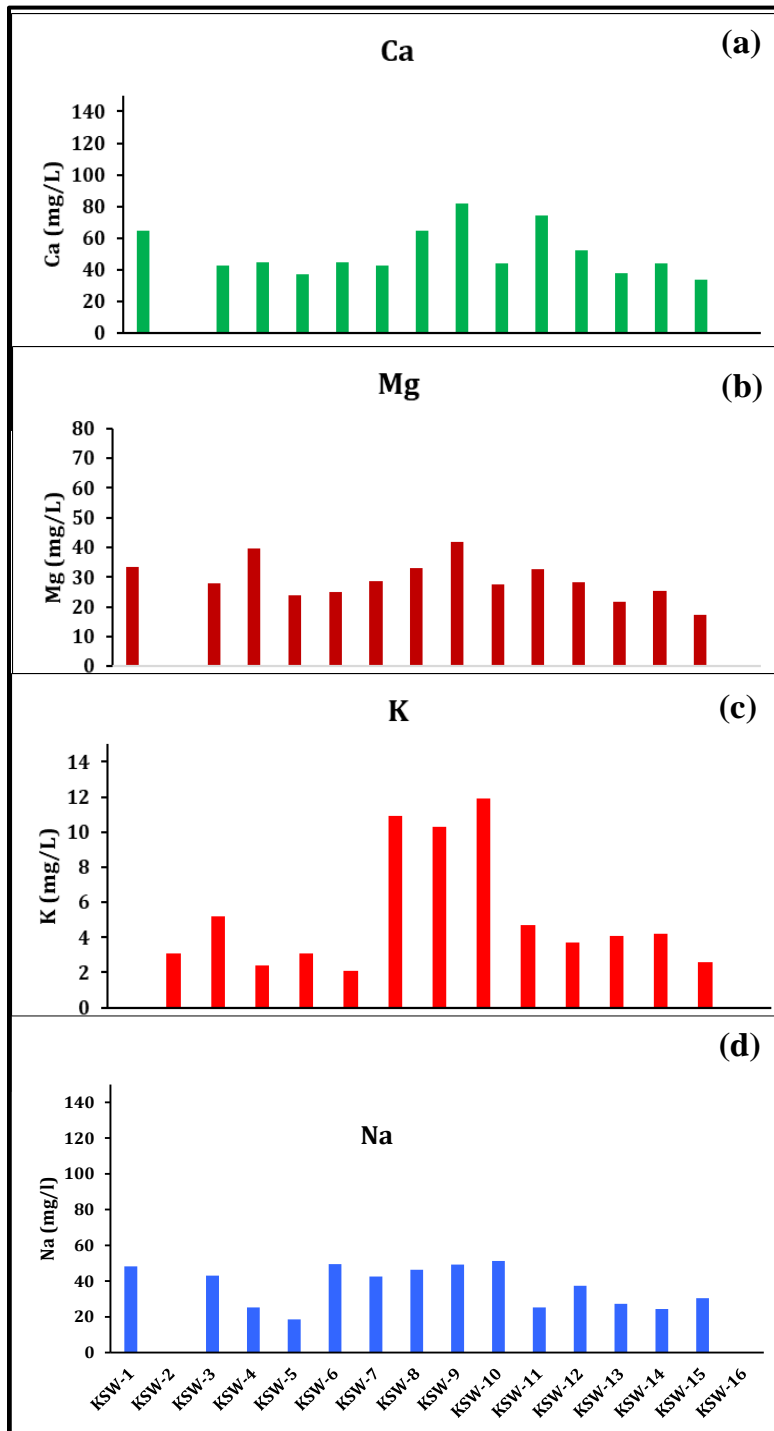


Figure 11: (a) Calcium (b) Sodium (c) Magnesium (d) Potassium Concentrations in surface-water samples collected from monitoring locations KSW-1 to KSW-16 in the study area (pre-monsoon season).



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Calcium (Ca):

Calcium is one of the major dissolved cations in surface waters of the NTPC Khargone study area. Generally, it exceeds the concentrations of magnesium, sodium, and potassium in a majority of the analysed samples. The dominance of calcium reflects the influence of carbonate dissolution, interactions with alluvial sediments, and water–rock interactions, with an additional localized contribution from ash–water interactions in operational and industrial water bodies. On average, calcium contributes a substantial proportion of the total cationic charge balance (TZ⁺), underscoring its importance in controlling water hardness and buffering capacity.

During the pre-monsoon season, calcium concentrations in surface water samples from natural and raw water sources range from approximately 25 to 82 mg/L, while industrial and operational surface waters exhibit relatively higher calcium concentrations, ranging from about 52 to 97 mg/L (**Figure 11a**). The average calcium concentration in natural and source waters is typically around 45–55 mg/L. In contrast, surface-water samples collected from the ash-lagoon system (KSW-8 to KSW-12) exhibit noticeably higher mean calcium levels. This enrichment is attributable to recirculation within the lagoon, evaporative concentration, and dissolution of calcium-bearing phases present in deposited fly ash and associated carbonate materials. Because these waters are in direct contact with stored fly ash and represent percolation or contact water within the ash-handling lagoon, they may be more appropriately described as ash-lagoon contact water or ash-influenced water, rather than natural surface water. Thus, the elevated calcium concentrations in samples KSW-8 to KSW-12 are best interpreted as reflecting ash-interaction–driven mineral enrichment under evaporative and recirculating lagoon conditions, rather than background geogenic hydrochemistry.

According to BIS IS 10500:2012, calcium has an acceptable limit of 75 mg/L and a permissible limit of 200 mg/L in the absence of an alternate drinking water source. The evaluation of the analytical results indicates that all natural surface waters and raw water sources fall within the BIS acceptable limits, confirming their suitability for abstraction and use after conventional treatment. Although some industrial and operational waters exhibit calcium concentrations marginally above the acceptable





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limit, these waters are not intended for potable use and remain well within the permissible limit, posing no regulatory or health concern.

Overall, the distribution of calcium in surface waters of the NTPC Khargone area reflects a combination of natural geochemical controls and localized industrial processes, contributing to moderate hardness without indicating any adverse environmental or compliance-related issues during the pre-monsoon period.

Sodium (Na):

Sodium in surface water systems is derived primarily from atmospheric deposition, dissolution of evaporitic residues, and chemical weathering of sodium-bearing silicate minerals. Weathering of feldspar and feldspathoid minerals, such as albite, anorthite, orthoclase, and microcline, is the principal geogenic source of sodium in natural waters. In the NTPC Khargone study area, sodium represents the second most dominant cation after calcium, exceeding magnesium and potassium concentrations in the majority of analysed surface water samples. On average, sodium accounts for a significant fraction of the total cationic charge balance (TZ⁺), underscoring its role in controlling ionic strength and hydro-chemical facies.

During the pre-monsoon season, sodium concentrations in natural surface waters and raw water sources range from approximately 18 to 56 mg/L. In contrast, industrial and operational surface waters exhibit relatively higher sodium concentrations, typically ranging from about 45 to 97 mg/L (**Figure 11 d**). The elevated sodium levels observed in industrial waters can be attributed to evaporative concentration, repeated recirculation, and localized interaction with ash and alkaline materials, rather than saline intrusion or anthropogenic contamination.

According to BIS IS 10500:2012 and WHO guidelines, sodium concentrations below 200 mg/L are considered acceptable from an aesthetic and health perspective. Evaluation of the analytical results indicates that all surface water samples from natural, raw water, and industrial zones fall well within the prescribed guideline value, confirming the absence of sodium-related salinity or sodicity concerns. Furthermore, the consistently high Na⁺/Cl⁻ ratios observed across surface water samples support the inference that





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sodium enrichment is predominantly geogenic, linked to silicate weathering and operational concentration effects rather than chloride-driven contamination.

Overall, the distribution of sodium in surface waters of the NTPC Khargone area reflects a combination of natural weathering processes and controlled industrial influence, resulting in a mixed Ca–Na–HCO₃ hydro-chemical facies without posing any regulatory or environmental risk during the pre-monsoon period.

Magnesium (Mg²⁺):

Magnesium is a naturally abundant element in the Earth's crust and a common constituent of surface waters, with geogenic sources contributing far more magnesium than anthropogenic inputs. The principal sources of magnesium in natural waters include the weathering of ferromagnesian minerals in igneous rocks, the dissolution of magnesium carbonates in sedimentary formations, and interaction with alluvial sediments. In addition, the high solubility of magnesium sulphate and magnesium chloride facilitates its mobilization into surface water systems under favorable hydro-chemical conditions.

In the NTPC Khargone study area, magnesium contributes a moderate proportion of the total cationic charge balance (TZ⁺) during the pre-monsoon season. On average, Mg²⁺ accounts for approximately 10–15% of the total cations in natural and raw water surface waters, with a slightly higher contribution observed in industrial and operational surface waters, reflecting enhanced water–solid interaction and evaporative concentration effects. During the pre-monsoon period, magnesium concentrations in natural surface waters range from about 17 to 44 mg/L, while industrial and impacted surface waters show concentrations ranging from approximately 28 to 42 mg/L (**Figure 11 b**).

The combined presence of calcium and magnesium governs the hardness of surface waters in the study area, resulting in moderately hard to hard water. According to BIS IS 10500:2012, magnesium has an acceptable limit of 30 mg/L and a permissible limit of 100 mg/L in the absence of an alternate drinking water source. The evaluation of analytical results indicates that most natural surface waters and raw water sources comply with the acceptable limit. At the same time, marginal exceedances at a few





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industrial and operational locations remain well within the permissible limit and are not relevant to potable use.

Overall, the observed magnesium distribution in surface waters of the NTPC Khargone area reflects natural mineral weathering processes and localized operational influences, contributing to water hardness without indicating any adverse environmental or regulatory concern during the pre-monsoon season.

Potassium (K⁺):

Although potassium (K⁺) is nearly as abundant as sodium in igneous and metamorphic rocks, its concentration in natural waters is typically one order of magnitude lower than that of sodium. This relative scarcity is primarily due to the resistance of potassium-bearing minerals to chemical weathering and the strong tendency of potassium ions to become fixed in secondary clay minerals formed during weathering. As a result, potassium generally exhibits limited mobility in surface water and groundwater systems.

In the NTPC Khargone study area, potassium constitutes a minor but measurable component of the total cationic charge balance (TZ⁺) during the pre-monsoon season. On average, K⁺ contributes approximately 5–10% of the total cations in natural surface waters and raw water sources. In contrast, its contribution in industrial and operational surface waters is slightly lower, reflecting dilution by dominant calcium and sodium ions. During the pre-monsoon period, potassium concentrations in natural and source surface waters range from about 2 to 12 mg/L, whereas industrial and operational waters typically range from 3 to 12 mg/L (**Figure 11 c**).

The relatively low and stable potassium concentrations across all surface water zones indicate minimal anthropogenic enrichment, as potassium inputs from domestic or industrial sources are generally limited. Furthermore, the absence of anomalously high potassium values supports the inference that surface water chemistry is predominantly governed by natural geochemical processes and controlled operational influences, rather than fertilizer runoff or industrial discharge.

Both BIS (IS 10500:2012) and WHO drinking water guidelines do not prescribe a specific standard for potassium, as it does not pose a direct health risk at concentrations



commonly encountered in natural waters. Accordingly, the observed potassium levels in surface waters of the NTPC Khargone area do not present any regulatory, environmental, or health-related concern and are consistent with bicarbonate-dominated freshwater systems during the pre-monsoon season.

5.4.5 Major Anions (CO_3^- , HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , F^- & PO_4^{3-})

The anion chemistry of the analysed surface water samples during the pre-monsoon period indicates that bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), fluoride (F^-), and phosphate (PO_4^{3-}) constitute the principal anionic species across most sampling locations. The relative dominance of these anions varies systematically between natural surface waters, raw water sources, and industrial/operational waters, reflecting differences in geochemical control and anthropogenic influence.

Surface water samples collected from rivers, reservoirs, canals, and village ponds predominantly follow the anionic abundance order: $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^- > \text{NO}_3^- > \text{F}^- > \text{PO}_4^{3-}$, indicating strong control of carbonate dissolution, silicate weathering, and soil CO_2 interaction under alkaline conditions. The dominance of bicarbonate in these waters is consistent with the observed pH range and reflects the buffering capacity of

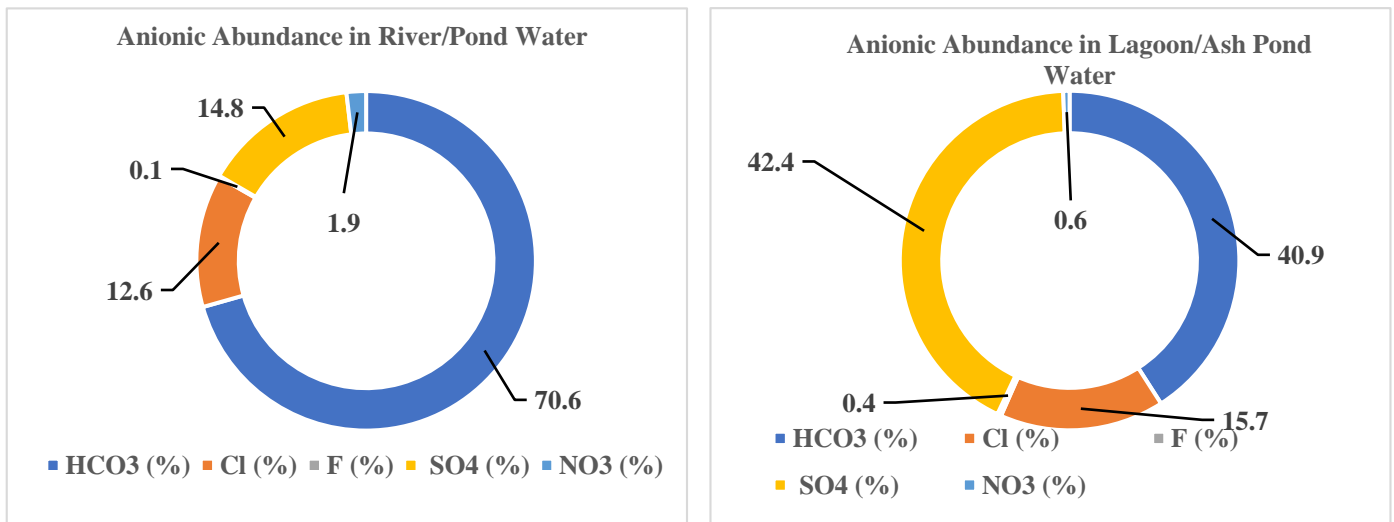


Figure 12: Anionic abundance in river/pond water samples, representing the relative proportions (%) of HCO_3^- , Cl^- , F^- , SO_4^{2-} , and NO_3^- .



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the Narmada basin's alluvial environment. Chloride and sulphate occur at comparatively lower concentrations, suggesting limited influence of saline intrusion or untreated anthropogenic inputs in natural surface waters.

In contrast, industrial and operational surface waters associated with cooling, reuse, and post-use systems exhibit a distinct anionic pattern characterized by the abundance order: $\text{SO}_4^{2-} > \text{HCO}_3^- > \text{Cl}^- > \text{F}^- > \text{NO}_3^- > \text{PO}_4^{3-}$ (Figure 12).

The relative enrichment of sulphate in these waters reflects ash-water interaction, dissolution of sulphate-bearing phases, recirculation effects, and evaporative concentration, rather than regional contamination. Despite this enrichment, sulphate concentrations remain within applicable BIS and CPCB permissible limits and are spatially confined to designated operational zones.

Overall, the contrasting anionic signatures between natural surface waters and industrial/operational waters highlight a clear geochemical separation between background hydro-chemical conditions and localized industrial influence. When interpreted in conjunction with cation chemistry and Piper diagram results, the anion distribution confirms that surface water chemistry in the NTPC Khargone study area is predominantly governed by natural weathering processes, with controlled, non-propagating industrial modification during the pre-monsoon season.

Bicarbonate (HCO_3^-)

Bicarbonate (HCO_3^-) in surface waters is derived primarily from soil-zone CO_2 and the chemical weathering of parent minerals. The subsurface soil environment is characterized by elevated partial pressure of CO_2 generated through decomposition of organic matter and root respiration, which reacts with infiltrating rainwater to form carbonic acid. This weak acid promotes the dissolution of carbonate minerals and silicate phases, releasing bicarbonate ions into surface and subsurface waters. As a result, bicarbonate constitutes the principal contributor to alkalinity and acid-neutralizing capacity in natural waters.

In the NTPC Khargone study area, bicarbonate is the dominant anion in most natural surface water samples during the pre-monsoon season, accounting for a major proportion of the total anionic charge balance (TZ⁻). The predominance of bicarbonate





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reflects strong rock–water interaction under alkaline conditions, consistent with the alluvial geomorphic setting of the Narmada basin. Carbonate (CO_3^{2-}) ions were not detected in any of the analysed samples, indicating that alkalinity is predominantly controlled by bicarbonate species under the prevailing pH conditions.

During the pre-monsoon period, bicarbonate concentrations in natural surface waters and raw water sources range from approximately 190 to 325 mg/L, with an average value of about 255–265 mg/L (Figure 12). Slightly elevated bicarbonate concentrations are observed in low-flow and semi-stagnant water bodies, reflecting prolonged water–sediment interaction and evaporative concentration. In industrial and operational surface waters, bicarbonate concentrations are generally comparable or marginally higher due to recirculation and interaction with alkaline materials, but remain within a similar compositional range.

As per BIS IS 10500:2012, the acceptable limit for alkalinity (as bicarbonate) is 200 mg/L, with a permissible limit of 600 mg/L in the absence of an alternate drinking water source. Evaluation of the analytical results indicates that most surface water samples fall within or marginally exceed the acceptable limit but remain well within the permissible limit, and therefore do not pose any health-related concern. Slightly elevated bicarbonate concentrations at a few locations are attributed to natural geochemical controls rather than anthropogenic pollution.

Overall, the dominance of bicarbonate in surface waters of the NTPC Khargone area confirms that carbonate and silicate weathering processes are the primary controls on surface water chemistry, contributing to stable pH conditions, moderate alkalinity, and bicarbonate-dominated hydro-chemical facies during the pre-monsoon season.

Chloride (Cl^-):

Chloride (Cl^-) concentrations in the analysed surface water samples of the NTPC Khargone study area exhibit low to moderate levels during the pre-monsoon season, indicating limited influence of saline intrusion or sewage contamination. Chloride concentrations range from approximately 21 mg/L in raw and natural surface waters (e.g., KSW-14) to about 90 mg/L in select industrial and operational waters (e.g., KSW-13) (Figure 12).





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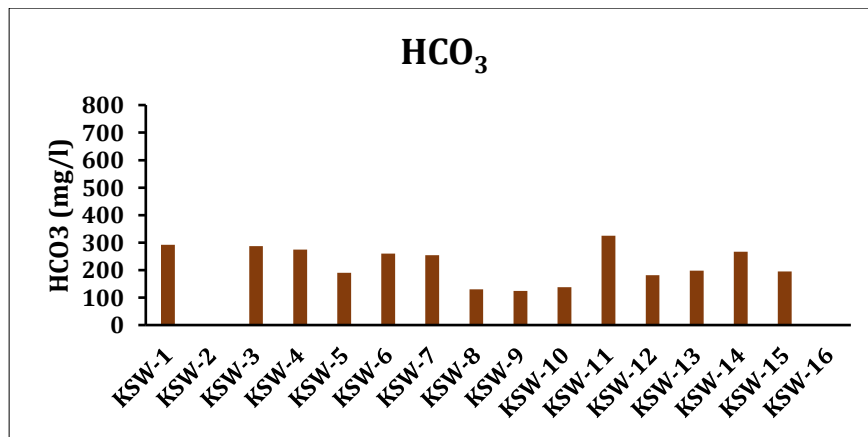
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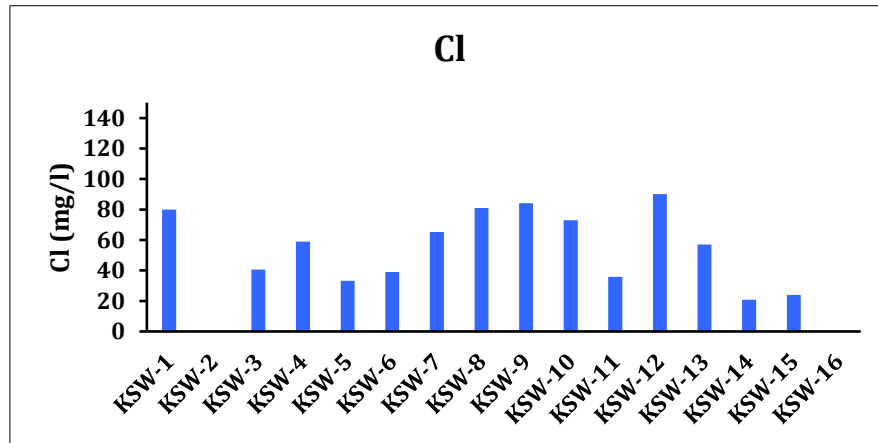
The average chloride concentration across all surface water samples remains well below 200 mg/L, which is significantly lower than the BIS acceptable limit of 250 mg/L. The relatively low chloride levels observed in rivers, reservoirs, and village ponds reflect minimal anthropogenic loading, while slightly elevated values in operational waters are attributable to evaporation, reuse cycles, and concentration effects, rather than external contamination. Chloride contributes a minor proportion of the total anionic charge balance (generally <15%), supporting the bicarbonate-dominated nature of surface waters in the study area.

Nitrate (NO_3^-) concentrations in surface water samples during the pre-monsoon period are generally low, ranging from below detection to approximately 15 mg/L, with an overall average of less than 5 mg/L (Figure 12) Slightly elevated nitrate values at a few locations are associated with localized domestic activities, cattle movement, or agricultural runoff, particularly in village pond environments under low-flow conditions. Importantly, all analysed nitrate concentrations are well within the BIS and WHO guideline value of 45 mg/L, indicating no risk of nitrate-related health impacts such as methemoglobinemia.

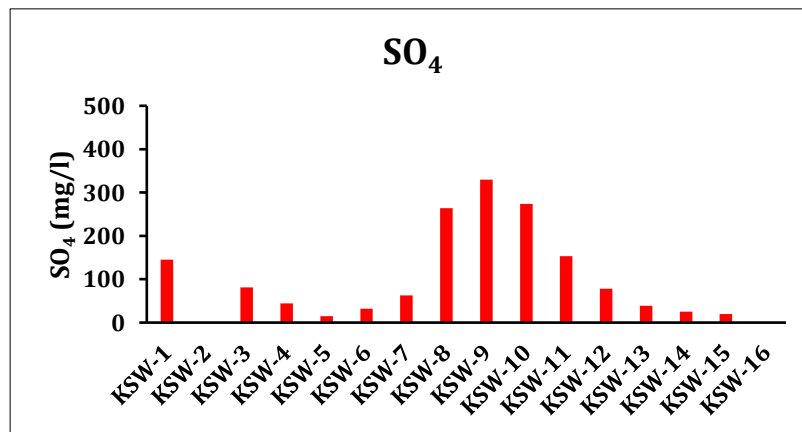


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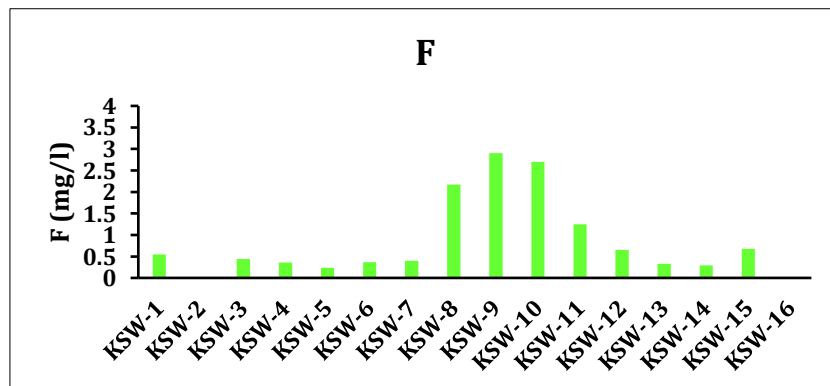




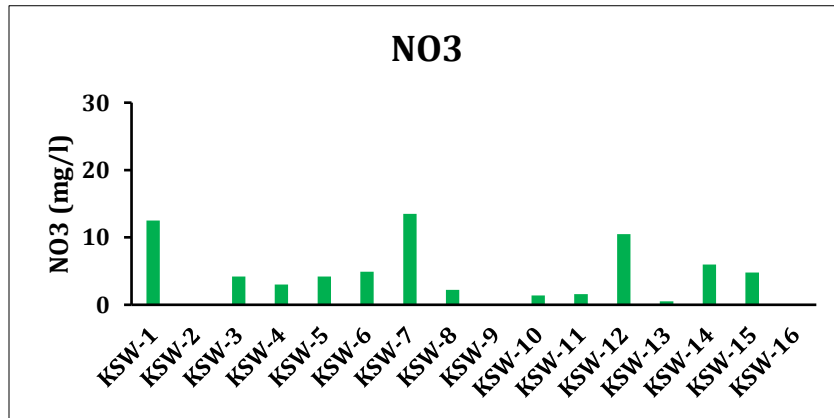
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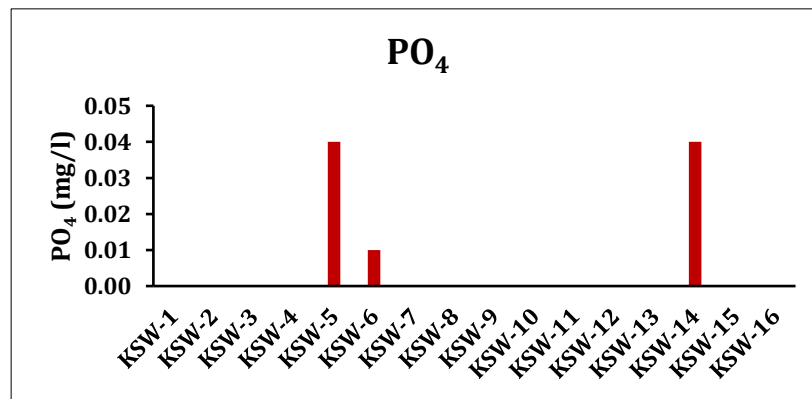
(c)



(d)



(e)



(f)

Figure 13: Bar-graph representation of pre-monsoon variation in major anions (a)

HCO₃⁻, (b)Cl⁻, (c)SO₄²⁻, (d)NO₃³⁻, (e)F & (f)PO₄²⁻ in surface water samples.

The combined chloride–nitrate signature of surface waters suggests that anthropogenic nutrient and saline inputs are limited and spatially restricted, with no evidence of widespread contamination. When interpreted alongside bicarbonate and sulphate distributions, the anionic chemistry confirms that surface water quality in the NTPC Khargone study area is primarily controlled by natural geochemical processes, with only localized and managed operational influence during the pre-monsoon season.

Sulphate (SO₄²⁻):

Sulphate (SO₄²⁻) is an important anion in surface water chemistry, derived from weathering of sulphate-bearing minerals, oxidation of sulphide minerals, dissolution of



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evaporitic residues, and interaction with industrial materials such as coal ash. According to BIS IS 10500:2012, sulphate has an acceptable limit of 200 mg/L and a permissible limit of 400 mg/L in the absence of an alternate drinking water source, owing to its potential to cause taste issues and laxative effects at elevated concentrations.

In the NTPC Khargone study area, sulphate concentrations in natural surface waters and raw water sources during the pre-monsoon season are generally low to moderate, ranging from approximately 15 to 145 mg/L, reflecting background geogenic contributions and limited anthropogenic influence. These values remain well within the BIS acceptable limit, indicating no sulphate-related concern for natural or source waters. In contrast, industrial and operational surface waters, particularly those influenced by cooling, reuse, and ash-handling systems, exhibit relatively higher sulphate concentrations ranging from about 153 to 330 mg/L (Figure 13). The elevated sulphate levels in these waters are attributable to ash-water interaction, dissolution of sulphate-bearing phases, evaporative concentration, and repeated recirculation, rather than external contamination.

Sulphate contributes a minor fraction of the total anionic charge balance in natural surface waters (generally <10%), whereas its contribution increases substantially in industrial and operational waters, where it may account for 30–45% of the total anions during the pre-monsoon period. Although sulphate concentrations in some operational waters exceed the acceptable limit of 200 mg/L, all observed values remain well within the permissible limit of 400 mg/L prescribed by BIS and within CPCB norms for industrial water management. These waters are not intended for potable use and are managed under controlled operational systems.

Overall, the sulphate distribution pattern clearly distinguishes background surface water chemistry from localized industrial influence, with elevated sulphate concentrations spatially confined to operational zones. When interpreted alongside bicarbonate dominance, cation chemistry, and Piper–Gibbs analyses, the sulphate behaviour confirms that natural surface waters in the NTPC Khargone area remain chemically stable and compliant, while higher sulphate levels in industrial waters reflect controlled and non-propagating operational processes during the pre-monsoon season.





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Nitrate (NO_3^-)

Nitrate (NO_3^-) is a key nitrogen species in surface water systems and is commonly used as an indicator of nutrient enrichment, redox conditions, and anthropogenic influence. Nitrate is highly soluble and stable under oxic conditions, entering surface waters through agricultural runoff, domestic wastewater discharge, manure application, and organic matter mineralization.

In the NTPC Khargone study area, nitrate concentrations in surface waters are generally low during the pre-monsoon season, reflecting limited nutrient loading and the absence of sustained sewage inputs. Most surface water samples exhibit nitrate levels well below 10 mg/L, and all observed values remain far below the BIS and WHO guideline value of 45 mg/L, indicating no nitrate-related health risk. Slightly elevated nitrate concentrations at a few village ponds and semi-stagnant surface water bodies can be attributed to localized domestic activities, cattle movement, and agricultural runoff, particularly under low-flow pre-monsoon conditions.

The distribution of nitrate indicates that nitrogen in surface waters of the NTPC Khargone area is present predominantly in an oxidized and environmentally stable form. The absence of widespread nitrate enrichment, together with generally adequate dissolved oxygen conditions, suggests that surface waters are not under significant organic or sewage stress. Furthermore, the lack of systematic nitrate enrichment in industrial and operational waters indicates that thermal power plant activities are not contributing to nitrogen pollution.

Overall, the nitrate chemistry of surface waters reflects a low nutrient status, oxic conditions, and localized non-industrial inputs, consistent with the observed BOD DO relationship and supporting the conclusion that surface water quality in the NTPC Khargone study area remains environmentally stable and compliant during the pre-monsoon season.





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Fluoride (F⁻):

Fluoride (F⁻) in surface water systems is derived primarily from the weathering and dissolution of fluoride-bearing minerals such as fluorite, apatite, and certain silicate phases, as well as from coal combustion residues and ash-water interaction in thermal power plant environments. The mobility of fluoride in water is strongly controlled by alkaline pH, bicarbonate concentration, calcium availability, residence time, and evaporative concentration, with alkaline and calcium-poor conditions favoring higher fluoride solubility. While fluoride is beneficial at low concentrations, prolonged exposure to elevated levels can lead to dental or skeletal fluorosis, making it a critical parameter in surface water quality assessment.

In the NTPC Khargone study area, fluoride concentrations in surface water samples collected during the pre-monsoon season range from 0.24 mg/L (KSW-5) to 2.90 mg/L (KSW-9). Natural surface waters and raw water sources generally exhibit low fluoride concentrations, typically between 0.24 and 0.68 mg/L (e.g., KSW-1, KSW-3, KSW-4, KSW-5, KSW-6, KSW-7, KSW-11, KSW-13, KSW-14, and KSW-15), reflecting background geogenic contributions under bicarbonate-dominated hydro-chemical conditions. These concentrations are well within the BIS and WHO guideline value of 1.5 mg/L for drinking water.

In contrast, industrial and operational surface waters show comparatively elevated fluoride concentrations. Notably, KSW-8 (2.17 mg/L), KSW-9 (2.90 mg/L), and KSW-10 (2.70 mg/L) exceed the BIS/WHO drinking water guideline of 1.5 mg/L, while KSW-12 (1.25 mg/L) approaches the guideline value. These elevated concentrations are spatially confined to cooling, recirculation, and post-use industrial water systems and are attributed to coal ash interaction, leaching of fluoride-bearing phases, evaporative concentration, and prolonged water reuse, rather than diffuse environmental contamination.

According to CPCB/FAO guidelines, fluoride concentrations up to 2.0 mg/L are permissible for industrial effluents discharged to inland surface waters or land for irrigation. While fluoride levels at KSW-9 and KSW-10 marginally exceed this value, these waters are not discharged outside the plant boundary and are managed under





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zero-liquid-discharge (ZLD) and controlled recirculation practices. Consequently, there is no exposure pathway to surrounding natural surface waters or human populations. Overall, fluoride contributes a minor fraction of the total anionic charge balance in most surface water samples and does not alter the dominant bicarbonate-controlled hydrochemical facies. The fluoride distribution clearly differentiates background surface waters from localized industrial/operational waters, confirming that elevated fluoride concentrations are process-related, spatially restricted, and effectively contained within the NTPC Khargone operational system during the pre-monsoon season.

Phosphate (PO₄)

Phosphate in surface water systems originates from a combination of natural geochemical processes and anthropogenic activities, including weathering of phosphorus-bearing minerals, soil erosion, agricultural runoff, domestic wastewater inputs, detergents, and organic matter decomposition. Although phosphate is not directly toxic to humans at low concentrations, it is a key limiting nutrient in freshwater ecosystems, and elevated levels can accelerate eutrophication, leading to excessive algal growth, reduced water transparency, and subsequent dissolved oxygen depletion.

In the NTPC Khargone study area, phosphate concentrations in surface water samples collected during the pre-monsoon season are generally very low, indicating minimal nutrient enrichment across most locations. Based on the revised dataset, phosphate concentrations range from 0.0001 mg/L (KSW-8, KSW-9, KSW-12) to 0.0360 mg/L (KSW-14). The majority of surface water samples—including riverine waters, raw water sources, and operational waters—exhibit phosphate concentrations below 0.005 mg/L, reflecting background natural conditions with negligible anthropogenic phosphate loading.

Slightly elevated phosphate concentrations are observed at KSW-5 (0.0350 mg/L) and KSW-14 (0.0360 mg/L), with moderately higher values at KSW-6 (0.0099 mg/L) and KSW-4 (0.0043 mg/L). These locations correspond primarily to village ponds or semi-stagnant surface water bodies, where localized domestic wastewater inputs, detergent usage, organic matter accumulation, and limited water exchange during the pre-monsoon period may contribute to marginal phosphate enrichment. Importantly, even





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these higher values remain well below ecologically critical eutrophication thresholds (>0.1 mg/L).

At an institutional level, BIS and WHO do not prescribe a drinking water standard for phosphate, as it does not pose a direct health risk at concentrations typically found in natural waters. Additionally, all observed phosphate concentrations are well below the CPCB guideline value of 5 mg/L for industrial effluent discharge into inland surface waters. Therefore, no regulatory exceedances or environmental risks related to phosphate are identified in the study area.

Overall, phosphate contributes a negligible fraction of the total anionic charge balance in surface waters of the NTPC Khargone area and does not influence the dominant hydro-chemical facies. The spatial distribution of phosphate clearly indicates low nutrient status and absence of eutrophication risk, confirming that surface water quality is largely unaffected by nutrient pollution and that observed variations are localized, low-intensity, and non-industrial in origin during the pre-monsoon season.

5.4.6. Hydrochemical Facies

The Piper trilinear diagram provides an integrated representation of the major ion chemistry and hydrogeochemical facies of surface water in the NTPC Khargone area during the pre-monsoon season. The projection of surface water samples onto the cationic, anionic, and central diamond fields reveals distinct yet overlapping hydrochemical characteristics among industrial, managed, and ambient surface water categories, reflecting differences in source, flow regime, and anthropogenic influence.

In the cation triangle, the majority of surface water samples cluster within the Ca–Mg dominant field, indicating that alkaline earth metals ($\text{Ca}^{2+} + \text{Mg}^{2+}$) exceed alkali metals ($\text{Na}^+ + \text{K}^+$). This pattern is particularly pronounced in ambient surface water samples derived from rivers and village ponds, suggesting strong control of natural weathering of basaltic rocks and carbonate-bearing materials. Managed surface waters (reservoirs and canals) also follow a similar trend but with slightly higher relative sodium contribution, likely reflecting longer residence time and partial evaporation within regulated systems. Industrial surface waters show limited dispersion toward the Na^++K^+ apex, yet do not indicate sodium dominance.



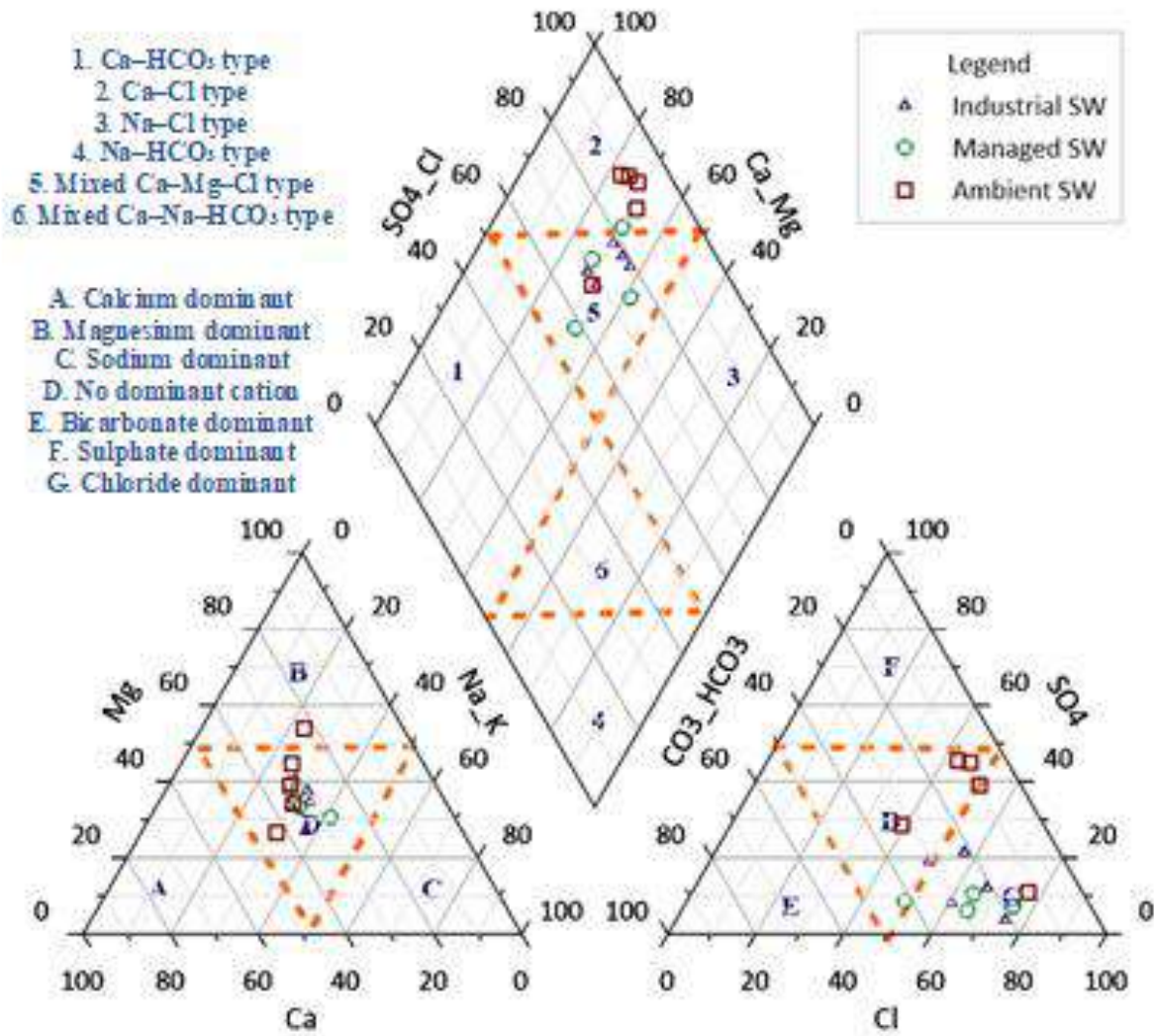


Figure 14: Piper Trilinear Diagram Showing Hydrogeochemical Facies of Surface Water in the NTPC Khargone Study Area (Pre-monsoon 2025).

The diagram illustrates the relative distribution of major cations (Ca^{2+} , Mg^{2+} , $\text{Na}^{+}+\text{K}^{+}$) and anions ($\text{HCO}_3^{-}+\text{CO}_3^{2-}$, Cl^{-} , SO_4^{2-}) for surface water samples classified into Industrial Surface Water (Core Zone), Managed Surface Water (Reservoir & Canal Zone), and Ambient Surface Water (Village & Riverine Zone). Dashed fields indicate dominant hydrochemical facies.



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The anion triangle demonstrates that most surface water samples plot within the bicarbonate-dominant ($\text{HCO}_3^- + \text{CO}_3^{2-}$) field, with secondary contributions from chloride and sulphate. Ambient surface waters are largely bicarbonate-rich, consistent with CO_2 -driven weathering processes and natural alkalinity generation. Managed surface waters occupy intermediate positions between bicarbonate and chloride-sulphate fields, reflecting mixing of natural waters with regulated storage effects. A few industrial surface water samples exhibit relatively higher sulphate and chloride proportions, attributable to process-related water use and concentration effects, though without overwhelming dominance.

In the central diamond field, surface water samples predominantly fall within the Ca-Mg- HCO_3 facies, confirming that surface waters across the study area are mainly governed by rock-water interaction rather than anthropogenic salinization. A limited number of samples trend toward Ca-Mg- SO_4 -Cl or mixed Ca-Na- HCO_3 -Cl facies, particularly within industrial and managed surface waters. These transitional facies reflect localized inputs, evaporation, and concentration effects, rather than widespread contamination.

Importantly, no surface water samples plot within the Na-Cl (saline) facies, indicating the absence of salinity dominance or industrial brine influence. The overall facies distribution suggests that weak acid anions (HCO_3^-) dominate over strong acids ($\text{SO}_4^{2-} + \text{Cl}^-$), which is characteristic of freshwater systems in basaltic terrains.

The Piper diagram collectively indicates that:

- Surface water chemistry is largely controlled by natural geochemical processes, especially silicate and carbonate weathering.
- Industrial surface waters, while showing some enrichment in sulphate and chloride, remain within mixed to bicarbonate facies and do not exhibit chemically distinct signatures indicative of off-site impact.
- Managed surface waters act as transitional systems, integrating inputs from natural sources and regulated storage conditions.





- Ambient surface waters, representing village and riverine environments, maintain fresh, bicarbonate-dominated chemistry suitable for multiple uses under prevailing standards.

Overall, the Piper diagram confirms that surface waters in the NTPC Khargone study area are hydrochemically fresh, bicarbonate-dominated, and internally consistent, with no evidence of regional-scale alteration due to thermal power plant operations during the pre-monsoon season.

5.4.7. Irrigation Suitability Assessment

Surface water irrigation suitability was assessed separately for ambient, managed, and industrial surface waters, recognizing their different hydrological roles. All surface water samples exhibit very low SAR values, clustering well within the S1 (low sodium hazard) class. This indicates:

- Negligible risk of soil sodicity,
- No adverse impact on soil structure or infiltration,
- Suitability for long-term irrigation use from a sodium perspective.

Surface water EC values vary across categories:

- Ambient and managed surface waters fall predominantly in C1–C2 (low to medium salinity) classes,
- Industrial surface waters extend into C3 (high salinity) class due to concentration effects and process water reuse.

Most surface water samples plot within C1–S1 and C2–S1 classes, indicating excellent to good irrigation quality. Industrial surface water samples plot in C3–S1, suggesting that while sodium hazard remains low, salinity management is required if such waters are to be reused for irrigation.

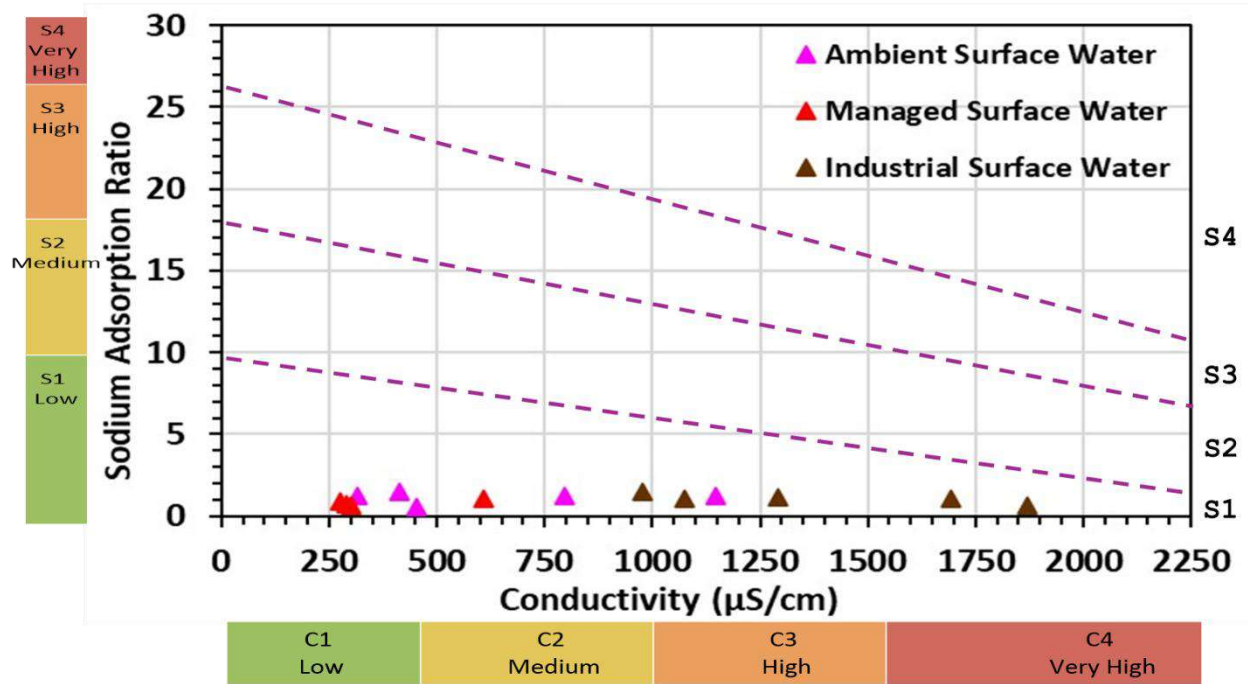


Figure 15: SAR–EC Classification Diagram for Surface Water

This figure illustrates the SAR–EC relationship for surface water samples categorized as ambient surface water, managed surface water, and industrial surface water. The diagram evaluates the irrigation suitability of surface waters under varying salinity and sodium hazard conditions, following standard USSL criteria.

5.4.6 Heavy-Trace Metal Distribution

Heavy metals in surface water are of considerable environmental significance due to their toxicity, persistence, and bioaccumulative nature. Unlike organic pollutants, heavy metals are non-biodegradable. They can enter the food chain through multiple pathways, including direct ingestion, aquatic uptake, and trophic transfer, leading to progressive accumulation in human and animal tissues over the long term. Even metals that are essential at trace levels—such as Zn, Cu, Fe, and Ni—may exert toxic effects when present at elevated concentrations. In surface water systems, heavy metals originate from a combination of natural geogenic sources (rock and soil weathering) and anthropogenic sources, including domestic wastewater, agricultural runoff, industrial operations, and coal combustion residues.



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The concentrations of ten heavy metals (As, Cd, Cr, Hg, Pb, Zn, Ni, Cu, Fe, and Ba) in surface water samples collected during the pre-monsoon season are presented in Table 8. The overall distribution pattern indicates clear spatial variability, reflecting differences between natural surface waters, raw water sources, and industrial/operational waters.

Table 8: Trace metal concentration ppb in the surface water (Ponds, Rivers, and Ash water) of the study area during pre-monsoon 2025.

Sample ID	As	Cd	Cr	Hg	Pb	Zn	Ni	Cu	Fe	Ba
KSW-1	1.0	0.0	0.7	1.38	2.087	2.54	1.3	2.7	1130	62
KSW-2	Dry									
KSW-3	0.4	0.1	1.2	0.7	2.1	3.7	1.0	BDL		19
KSW-4	0.6	0.0	1.8	0.3	3.0	15.6	1.0	BDL	519	28
KSW-5	2.2	0.1	45.7	0.4	10.5	73.7	47.4	193.0	40917	155
KSW-6	2.2	0.2	5.0	1.0	6.6	17.8	5.6	9.6	711	42
KSW-7	0.8	0.0	1.2	0.7	2.7	5.2	0.3	BDL	362	20
KSW-8	7.3	0.1	8.5	0.6	4.7	43.9	16.7	0.5	319	164
KSW-9	50.5	2.7	15.8	1.3	28.2	270.4	306.2	125.3	7345	249
KSW-10	7.7	0.0	1.3	0.8	4.4	2.9	14.9	BDL	145	137
KSW-11	0.7	0.2	0.9	1.0	14.7	13.7	0.8	BDL	88	24
KSW-12	1.9	0.0	1.1	1.3	1.6	2.7	1.9	3.8	718	45
KSW-13	2.0	0.1	0.7	0.8	0.5	5.1	5.9	BDL	208	25
KSW-14	2.4	0.1	0.9	0.9	0.7	6.2	6.8	BDL	235	29
KSW-15	1.4	0.0	6.5	0.5	5.0	13.7	9.4	17.7	4207	47
KSW-16	Dry									

Iron (Fe):

Iron (Fe) is an essential trace element for human nutrition and aquatic life; however, elevated concentrations in water primarily cause aesthetic, operational, and consumer acceptability issues rather than direct health impacts. High iron concentrations impart an inky or bitter taste, cause reddish-brown discoloration, and increase turbidity due to oxidation and precipitation of ferric hydroxides upon exposure to air. Groundwater or surface water containing dissolved ferrous iron often appears clear at the source but rapidly develops rusty coloration and sediment when aerated. Iron enrichment may also





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promote the growth of iron-oxidizing bacteria such as Gallionella, Leptothrix, and Crenothrix, which can clog intake structures, pipelines, and distribution systems, leading to the commonly reported “red water” problem. These issues are mainly of aesthetic and operational concern, and BIS standards for iron are therefore based on acceptability rather than toxicity.

In the NTPC Khargone study area, iron concentrations in surface water samples collected during the pre-monsoon season show wide spatial variability, reflecting differences in geomorphic setting, redox conditions, sediment interaction, and localized anthropogenic inputs. Iron concentrations in natural riverine and flowing surface waters are generally moderate, whereas significantly elevated concentrations are recorded in stagnant ponds and polluted surface water bodies. Based on the analytical results, iron concentrations range from as low as ~0.09–0.36 mg/L at relatively cleaner surface waters (e.g., KSW-10, KSW-11, KSW-13) to very high values exceeding 1 mg/L at several locations. Exceptionally high iron concentrations are observed at KSW-5 (~40.9 mg/L), KSW-9 (~7.35 mg/L), KSW-15 (~4.21 mg/L), and KSW-1 (~1.13 mg/L). These sites correspond predominantly to polluted or semi-stagnant surface water bodies, including village ponds and post-use industrial waters, where organic matter accumulation, reducing micro-environments, sediment resuspension, and wastewater inflow enhance iron mobilization.

The elevated iron concentrations observed at village ponds are consistent with domestic wastewater discharge, religious activities, cattle use, and organic-rich sediments, rather than direct industrial discharge. Similar iron enrichment patterns have been documented in earlier baseline investigations in the region, indicating that high iron at these locations represents a persistent, site-specific condition controlled largely by natural sedimentary iron content and local land-use practices. In contrast, operational and lagoon waters associated with NTPC Khargone show comparatively lower and more uniform iron concentrations, generally remaining below the CPCB effluent discharge limit of 3.0 mg/L prescribed under the Environment (Protection) Act, confirming effective operational control.



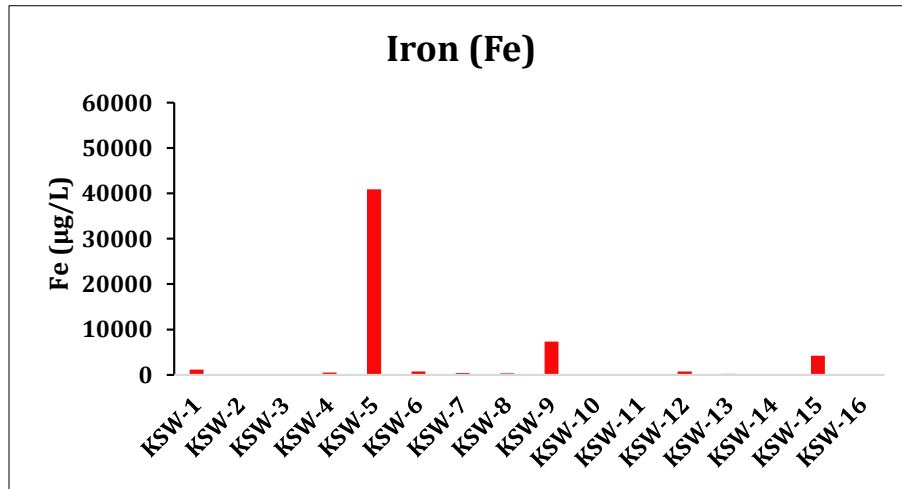


Figure 16: Iron (Fe) concentration (µg/L) across the various sampling locations.

According to BIS IS 10500:2012, the acceptable limit for iron in drinking water is 0.3 mg/L, with no relaxation in permissible limits due to aesthetic concerns. While several surface water samples exceed this guideline, these waters are not used for potable supply and therefore do not constitute a public health concern. Moreover, NTPC Khargone operates under a zero-liquid-discharge (ZLD) framework, ensuring that iron-rich operational waters are not discharged into surrounding natural water bodies. Nevertheless, continued monitoring and appropriate treatment are recommended for any future reuse or emergency discharge scenarios, to prevent staining, turbidity, and consumer acceptance issues.

Overall, the distribution of iron in surface waters around NTPC Khargone is dominated by geogenic sources and localized non-industrial inputs, with no evidence of regional-scale contamination or off-site industrial impact. Elevated iron concentrations are spatially restricted, operationally managed, and primarily of aesthetic and infrastructural significance, rather than environmental or health concern during the pre-monsoon season.

Zinc (Zn)

Zinc (Zn) is an essential trace element required for normal biological functions in humans, animals, and aquatic organisms, and is commonly present in natural waters in the form of dissolved salts or organic complexes. The solubility and mobility of zinc



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in surface water are strongly influenced by pH, alkalinity, carbonate concentration, and redox conditions. Under alkaline and bicarbonate-rich conditions, zinc tends to precipitate as basic zinc carbonate, thereby limiting its dissolved concentration, whereas lower pH and higher organic content enhance zinc solubility. In uncontaminated natural waters, zinc concentrations are typically low, generally <0.01 mg/L in surface water and <0.05 mg/L in groundwater, reflecting geogenic background levels.

In the NTPC Khargone study area, zinc concentrations in surface water samples collected during the pre-monsoon season show considerable spatial variability, reflecting differences in land use, water residence time, and localized anthropogenic influence. Zinc concentrations in natural surface waters and raw water sources generally remain low to moderate, whereas significantly elevated concentrations are observed at a few polluted or operational surface water locations. Based on the analytical results, zinc concentrations range from as low as ~2.5–5 µg/L in cleaner surface waters to substantially higher values at KSW-5 (~73.7 µg/L) and KSW-9 (~270.4 µg/L). These elevated concentrations are spatially associated with stagnant or post-use surface waters, where industrial reuse cycles, ash interaction, evaporative concentration, and organic matter accumulation enhance zinc mobilization.

Among the sampled locations, KSW-9 and KSW-5 record the highest zinc concentrations, corresponding to polluted surface waters rather than natural riverine systems. The elevated zinc at these locations is likely influenced by a combination of industrial operational inputs, localized wastewater inflow, and comparatively lower pH conditions, which increase zinc solubility. In contrast, ash pond and operational waters show relatively lower and more uniform zinc concentrations, indicating effective containment and controlled water management within the plant premises.



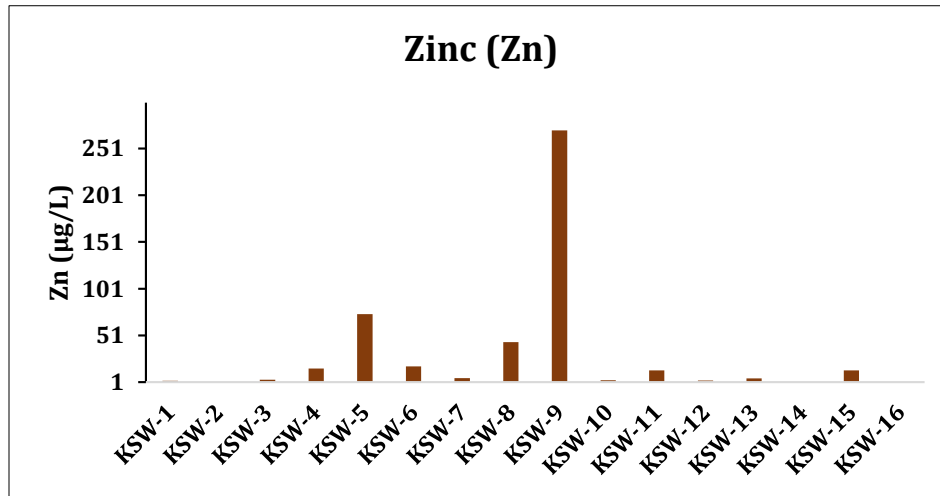


Figure 17: Zinc (Zn) concentration ($\mu\text{g/L}$) across the various sampling locations.

According to BIS IS 10500:2012, the desirable limit for zinc in drinking water is 5,000 $\mu\text{g/L}$, with a permissible limit of 15,000 $\mu\text{g/L}$ in the absence of an alternate source. Evaluation of the analytical results indicates that all surface water samples, including those showing localized enrichment, remain well within the BIS acceptable and permissible limits. Consequently, zinc does not pose any health-related risk in the study area, and the observed concentrations are primarily of geochemical and operational relevance rather than regulatory concern.

Overall, the distribution of zinc in surface waters around NTPC Khargone reflects background geogenic contributions with localized enrichment in stagnant and operational waters, without evidence of widespread contamination or off-site propagation. Elevated zinc concentrations are spatially restricted, process-related, and effectively managed, and do not impact the quality of natural surface waters used for domestic or agricultural purposes during the pre-monsoon season.

Arsenic (As):

Arsenic (As) is a toxic trace element that typically occurs in natural surface waters at very low concentrations, generally below 1–2 $\mu\text{g/L}$, primarily derived from the weathering of arsenic-bearing minerals, sulphide phases, and volcanic or sedimentary deposits. Elevated arsenic concentrations in aquatic systems are often associated with reducing

conditions, high iron availability, desorption from iron oxyhydroxides, and anthropogenic inputs, particularly in areas influenced by mining, coal combustion residues, and industrial activity. Long-term exposure to elevated arsenic levels through drinking water poses serious health risks, including skin lesions, cardiovascular disorders, and carcinogenic effects, making arsenic a critical parameter in water quality assessment.

In the NTPC Khargone study area, arsenic concentrations in surface water samples collected during the pre-monsoon season exhibit marked spatial variability. Based on the analytical results, arsenic concentrations in natural and raw surface waters generally range from below detection to about 2–8 $\mu\text{g/L}$, reflecting background geogenic levels. However, significantly elevated arsenic concentrations are recorded at a few polluted and operational surface water locations, notably KSW-9 (~50.5 $\mu\text{g/L}$) and KSW-8 (~7.3 $\mu\text{g/L}$). These sites correspond to industrial/operational or polluted surface water bodies, where ash–water interaction, coal combustion residues, evaporative concentration, and prolonged water residence time contribute to localized arsenic enrichment under pre-monsoon conditions.

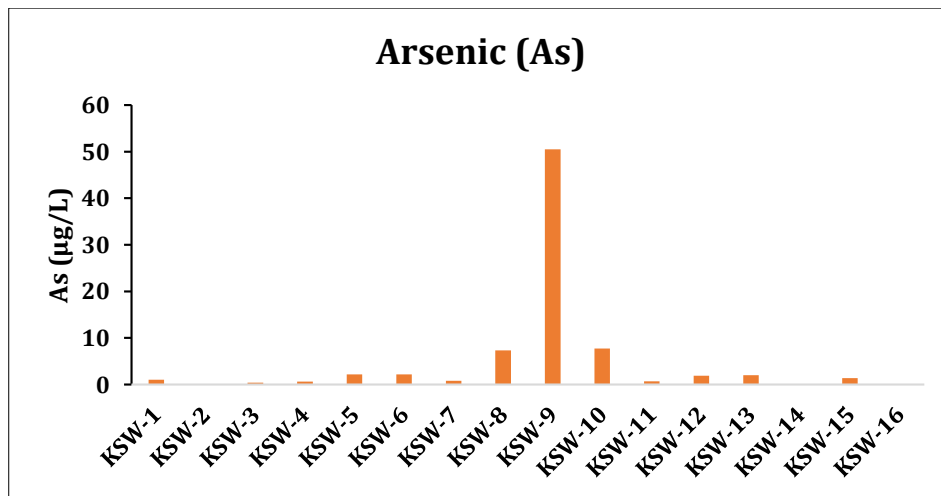


Figure 18: Arsenic (As) concentration ($\mu\text{g/L}$) across the various sampling locations.

According to BIS IS 10500:2012, the acceptable limit for arsenic in drinking water is 10 $\mu\text{g/L}$, with a permissible limit of 50 $\mu\text{g/L}$ in the absence of an alternate source. Evaluation of the results indicates that most natural surface waters and raw water



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sources comply with the BIS acceptable limit, whereas KSW-9 marginally exceeds the permissible limit. Importantly, this location represents polluted/operational surface water and is not used for drinking or domestic supply. From an industrial compliance perspective, arsenic concentrations in operational and ash-affected waters remain well below the CPCB effluent discharge standard of 0.2 mg/L (200 µg/L) prescribed under the Environment (Protection) Act, 1986, confirming regulatory conformity.

The spatial confinement of elevated arsenic concentrations to industrial or polluted surface water bodies, together with the implementation of zero-liquid-discharge (ZLD) and controlled recirculation practices at NTPC Khargone, ensures that arsenic-enriched waters do not migrate into surrounding natural surface water systems. No evidence of regional arsenic contamination or downstream propagation is observed.

Overall, the distribution of arsenic in surface waters around NTPC Khargone reflects predominantly geogenic background conditions with localized operational enrichment, rather than widespread contamination. While arsenic exceedances at isolated locations warrant continued monitoring and operational vigilance, the integrated assessment indicates no significant human health or ecological risk to natural surface waters during the pre-monsoon season.

Lead (Pb):

Lead (Pb) is a toxic non-essential trace metal widely used in the manufacture of lead-acid batteries, alloys, pigments, cables, and solder, and its presence in water is of particular concern due to its cumulative toxicity and persistence. In natural surface waters, lead is typically present at very low concentrations because of its limited solubility and strong adsorption to sediments and particulate matter. Elevated lead concentrations in surface waters are therefore more commonly associated with anthropogenic sources, including industrial activities, coal combustion residues, urban runoff, domestic wastewater, and corrosion of plumbing materials, rather than direct dissolution from geological formations. Chronic exposure to lead is linked to neurodevelopmental impairment, renal dysfunction, cardiovascular diseases, reproductive toxicity, and adverse pregnancy outcomes, making it a critical parameter for water quality assessment.



In the NTPC Khargone study area, lead concentrations in surface water samples collected during the pre-monsoon season exhibit pronounced spatial variability. Based on the analytical results, lead concentrations in natural surface waters and raw water sources are generally low, typically ranging from ~0.5 to 5 $\mu\text{g/L}$, reflecting background geogenic levels and limited anthropogenic influence. However, substantially elevated lead concentrations are recorded at a few polluted or operational surface water locations, most notably KSW-9 (~28.2 $\mu\text{g/L}$) and KSW-11 (~14.7 $\mu\text{g/L}$), with moderate enrichment also observed at KSW-5 and KSW-15. These sites correspond to polluted surface waters, post-use industrial waters, or semi-stagnant environments, where coal ash interaction, industrial reuse cycles, accumulation of suspended particulates, and reduced dilution during the pre-monsoon period enhance lead mobilization.

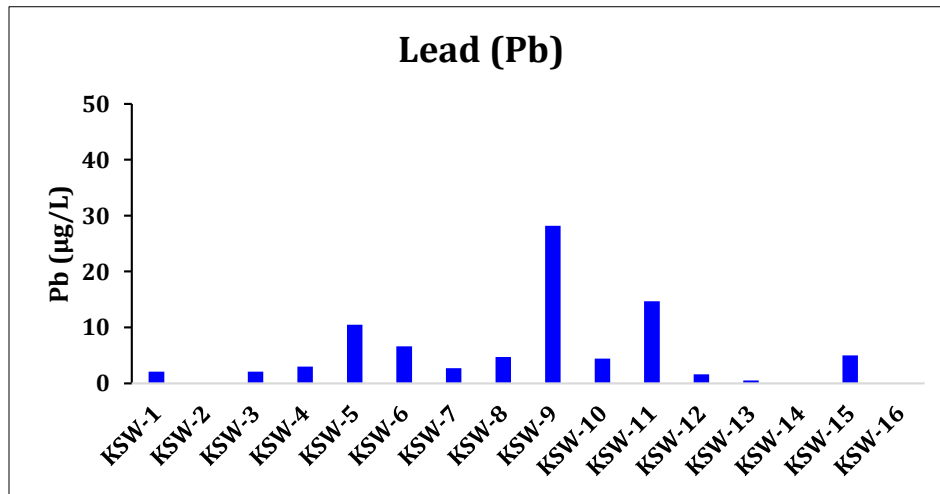


Figure 19: Lead (Pb) concentration ($\mu\text{g/L}$) across the study sampling locations.

According to BIS IS 10500:2012 and WHO guidelines, the acceptable limit for lead in drinking water is 10 $\mu\text{g/L}$. Evaluation of the results indicates that most natural surface waters and raw water sources comply with this guideline, while exceedances are confined to polluted or operational surface waters, which are not used for drinking or domestic purposes. From an industrial compliance perspective, all measured lead concentrations remain well below the CPCB effluent discharge standard of 0.2 mg/L (200 $\mu\text{g/L}$) prescribed under the Environment (Protection) Act, 1986, confirming regulatory conformity for operational waters.



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The spatial restriction of elevated lead concentrations to a limited number of polluted and operational locations, together with the implementation of zero-liquid-discharge (ZLD) and controlled recirculation practices at NTPC Khargone, ensures that lead-enriched waters do not impact surrounding natural surface water bodies. No evidence of widespread lead contamination or downstream propagation is observed.

Overall, the distribution of lead in surface waters around NTPC Khargone reflects localized anthropogenic enrichment superimposed on low natural background levels, rather than regional contamination. While isolated exceedances in polluted surface waters warrant continued monitoring and management, the integrated assessment indicates no significant human health or ecological risk to natural surface waters during the pre-monsoon season.

Chromium (Cr):

Chromium (Cr) occurs in natural waters primarily as trivalent chromium [Cr(III)], which is relatively insoluble and less toxic, whereas hexavalent chromium [Cr(VI)] is highly mobile and toxic. In surface water systems, chromium originates from weathering of chromium-bearing minerals, soil erosion, and anthropogenic sources such as industrial effluents, coal combustion residues, pigments, and metal-processing activities. The mobility and toxicity of chromium are strongly influenced by pH, redox conditions, and organic matter content, with alkaline and oxidizing environments favoring greater Cr(VI) solubility.

In the NTPC Khargone study area, the concentration of total chromium in surface water samples collected during the pre-monsoon season is generally low, indicating minimal chromium enrichment under prevailing hydrogeochemical conditions. Based on analytical results, chromium concentrations in surface waters range from ~0.7 to 15.8 µg/L, with most natural surface water and raw water samples exhibiting concentrations well below 5 µg/L. Slightly elevated chromium concentrations are observed at polluted or operational surface water locations, particularly KSW-5 (~45.7 µg/L) and KSW-9 (~15.8 µg/L), where industrial reuse cycles, ash-water interaction, and evaporative concentration under low-flow pre-monsoon conditions enhance chromium accumulation. In contrast, chromium concentrations in the ash pond and controlled



operational waters remain relatively uniform and low, reflecting effective containment and management practices.

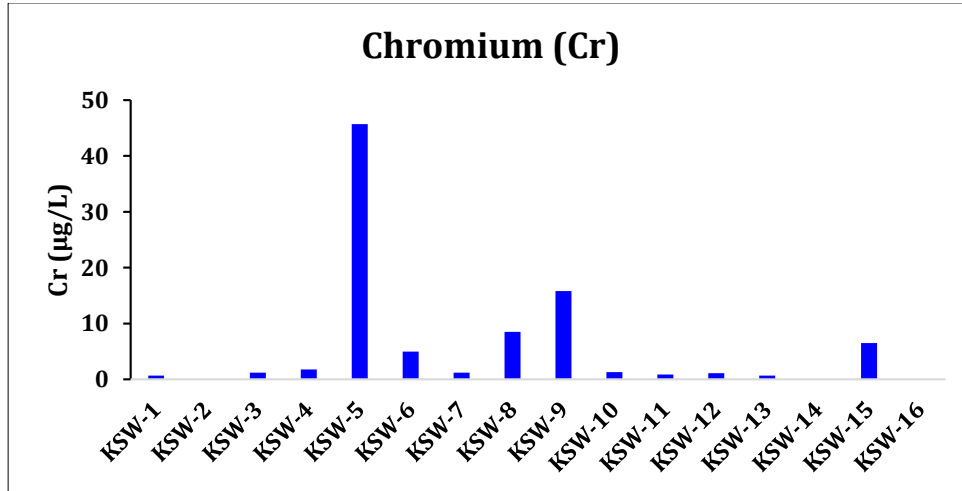


Figure 20: Chromium (Cr) concentration (µg/L) across the study sampling locations.

According to BIS IS 10500:2012 and WHO guidelines, the acceptable limit for total chromium in drinking water is 50 µg/L. Evaluation of the results indicates that none of the natural surface water or raw water samples exceed this limit, and even the highest observed concentrations at polluted locations remain below the prescribed drinking water standard. From an industrial compliance perspective, chromium concentrations in operational waters are also well within CPCB effluent discharge limits, confirming conformity with regulatory requirements.

Overall, the chromium distribution in surface waters around NTPC Khargone reflects predominantly geogenic background levels with localized enrichment at polluted and operational sites, rather than widespread contamination. The absence of chromium exceedances in natural surface waters, together with the spatial confinement of higher concentrations, indicates low environmental and human health risk during the pre-monsoon season. Continued monitoring is nevertheless recommended to ensure early detection of any changes associated with operational or land-use dynamics.

Cadmium (Cd):

Cadmium (Cd) is a non-essential and highly toxic trace metal, known for its cumulative behavior and long biological half-life. In aquatic environments, cadmium typically

originates from weathering of cadmium-bearing minerals, atmospheric deposition, and anthropogenic sources such as industrial effluents, coal combustion residues, fertilizers, and sewage inputs. Chronic exposure to cadmium through drinking water may result in renal dysfunction, skeletal damage, and carcinogenic effects, making it a critical parameter in water quality assessment.

In the NTPC Khargone study area, cadmium concentrations in surface water and ash pond water samples collected during the pre-monsoon season are found to be very low. Cadmium concentrations in surface water samples range from below detection limit (ND) to about 0.6 $\mu\text{g/L}$, while ash pond water samples show concentrations in the range of 0.1 to 0.3 $\mu\text{g/L}$, with an overall average concentration of approximately 0.2 $\mu\text{g/L}$. The consistently low concentrations indicate minimal cadmium input from both natural and anthropogenic sources during the monitoring period.

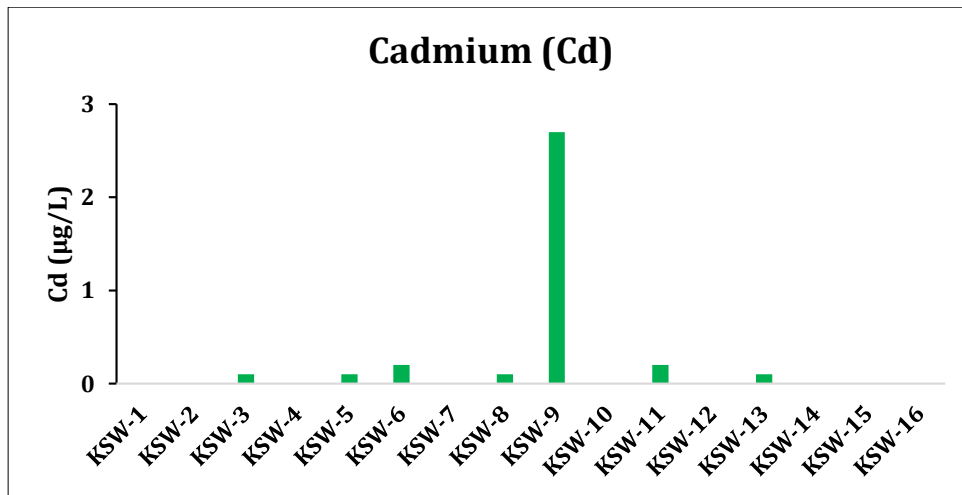


Figure 21: Cadmium (Cd) concentration ($\mu\text{g/L}$) across the study sampling locations.

According to BIS IS 10500:2012, the acceptable limit for cadmium in drinking water is 3 $\mu\text{g/L}$. Evaluation of the analytical results indicates that all analysed surface water and ash pond water samples remain well within this acceptable limit, confirming regulatory compliance. The absence of elevated cadmium concentrations further suggests that industrial activities and ash handling operations at NTPC Khargone are not contributing to cadmium contamination in surrounding surface waters.

Overall, cadmium levels in the study area pose no significant environmental or human health risk during the pre-monsoon season, and the surface waters remain chemically safe with respect to cadmium contamination..

Mercury (Hg):

Mercury (Hg) is a highly toxic trace metal with significant environmental and health implications due to its persistence, bioaccumulation, and potential for biomagnification in aquatic food chains. In surface water systems, mercury originates from natural sources such as rock weathering and atmospheric deposition, as well as anthropogenic activities including coal combustion, industrial effluents, and domestic wastewater inputs. Even at low concentrations, prolonged exposure to mercury can result in neurological, renal, and developmental disorders, making it a critical parameter for water quality monitoring.

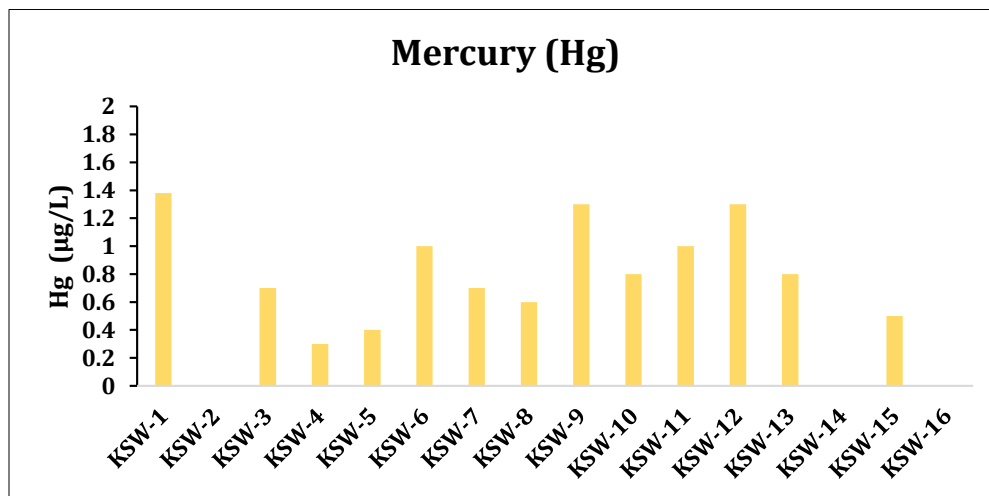


Figure 22: Mercury (Hg) concentration (µg/L) across the study sampling locations.

In the NTPC Khargone study area, mercury concentrations in surface water and ash pond water samples collected during the pre-monsoon season range from below detection limit (ND) to 3.1 µg/L, with the highest value observed at SW-09 (Salaiya pond). Ash pond water samples exhibit mercury concentrations between 1.2 and 2.0 µg/L, with average concentrations of approximately 0.95 µg/L in surface waters and 1.6 µg/L in ash pond waters, respectively. The elevated mercury concentrations observed at SW-09 and the reservoir raw water location are likely attributable to localized inputs



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from domestic wastewater, organic-rich sediments, and prolonged water residence time, rather than direct industrial discharge.

According to BIS IS 10500:2012, the acceptable limit for mercury in drinking water is 1 µg/L. Based on the analytical results, most surface water and all ash pond water samples comply with the BIS acceptable limit, except for Salaiya pond (SW-09) and the reservoir raw water sample, where mercury concentrations marginally exceed the guideline value. However, it is important to note that these waters are not used directly for drinking purposes. From an industrial compliance perspective, all measured mercury concentrations are well within the CPCB effluent discharge standard of 0.1 mg/L (100 µg/L) prescribed under the Environment (Protection) Act, confirming regulatory conformity.

Overall, mercury distribution in surface waters around NTPC Khargone shows localized enrichment at a few stagnant or polluted water bodies, while the majority of surface waters remain within acceptable limits. The observed mercury levels do not indicate widespread contamination or off-site industrial impact, though continued monitoring of identified locations with marginal exceedance is recommended to prevent long-term ecological or health concerns.

Nickel (Ni)

Nickel (Ni) is a naturally occurring trace metal commonly associated with ultramafic rocks, lateritic soils, and iron-rich sediments, and it may also enter surface waters through industrial activities, coal combustion residues, stainless-steel corrosion, and domestic wastewater. At low concentrations, nickel is considered biologically tolerable; however, prolonged exposure to elevated levels can cause dermatological, respiratory, and renal effects, making it an important parameter in surface water quality assessment. Nickel mobility in aquatic systems is controlled by pH, redox conditions, organic matter content, and adsorption onto iron and manganese oxides.

In the NTPC Khargone study area, nickel concentrations in surface water samples collected during the pre-monsoon season show distinct spatial variability. Nickel concentrations range from as low as ~0.3–1.9 µg/L in relatively clean surface waters to markedly elevated values at polluted and operational locations, particularly KSW-9



(~306.2 $\mu\text{g/L}$) and KSW-5 (~47.4 $\mu\text{g/L}$). Moderate enrichment is also observed at KSW-8 and KSW-10, indicating localized accumulation. These elevated concentrations are spatially associated with polluted surface waters, post-use cooling waters, and stagnant environments, where industrial reuse cycles, ash-water interaction, evaporative concentration, and reduced dilution during the dry season enhance nickel mobilization.

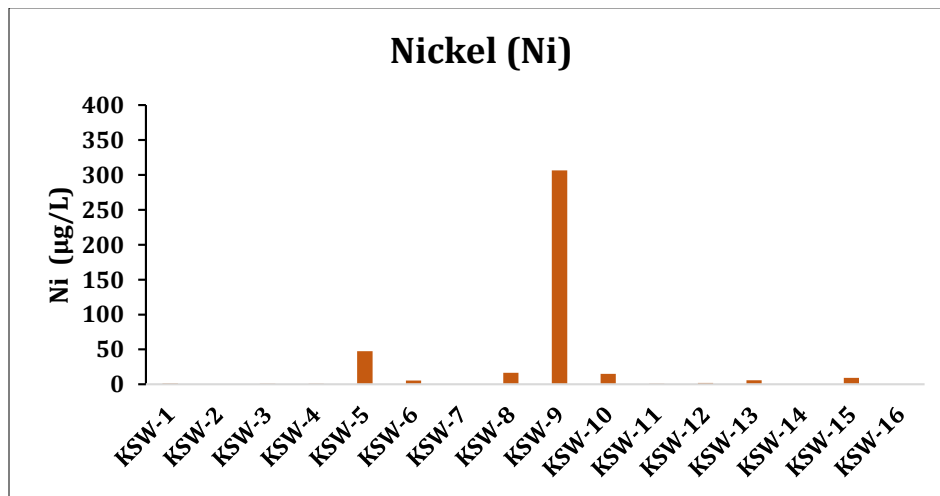


Figure 23: Nickel (Ni) concentration ($\mu\text{g/L}$) across the study sampling locations.

According to BIS IS 10500:2012, the acceptable limit for nickel in drinking water is 20 $\mu\text{g/L}$. Evaluation of the results indicates that most natural surface water samples comply with this guideline, whereas significant exceedances are observed only in polluted or operational surface waters that are not used for drinking or domestic purposes. From an industrial compliance standpoint, nickel concentrations remain within CPCB effluent discharge limits, and the adoption of zero-liquid-discharge (ZLD) practices prevents nickel-enriched waters from migrating into surrounding natural surface water bodies. Overall, nickel enrichment is localized and operationally controlled, posing no regional environmental or public health risk.

Copper (Cu)

Copper (Cu) is an essential trace element required for enzymatic and metabolic processes in living organisms; however, excessive copper concentrations in water can impart metallic taste, gastrointestinal irritation, and ecological toxicity. In surface waters, copper is derived from natural weathering of copper-bearing minerals, corrosion

of metal fittings, domestic wastewater, and industrial sources including coal combustion residues and cooling system components. Copper solubility increases under low pH and high organic matter conditions, while alkaline, bicarbonate-rich waters favor copper precipitation and adsorption.

In the NTPC Khargone study area, copper concentrations in surface water samples during the pre-monsoon season range from below detection to moderate levels in most natural waters, while substantially elevated concentrations are observed at a few polluted surface water locations. Copper concentrations are generally $<5 \mu\text{g/L}$ in riverine and raw water samples, but increase sharply at KSW-5 ($\sim 193.0 \mu\text{g/L}$) and KSW-9 ($\sim 125.3 \mu\text{g/L}$). Elevated copper is also noted at KSW-15 ($\sim 17.7 \mu\text{g/L}$) and KSW-6 ($\sim 9.6 \mu\text{g/L}$). These locations correspond to polluted or operational waters, where industrial reuse, ash-water interaction, and evaporative concentration enhance copper levels.

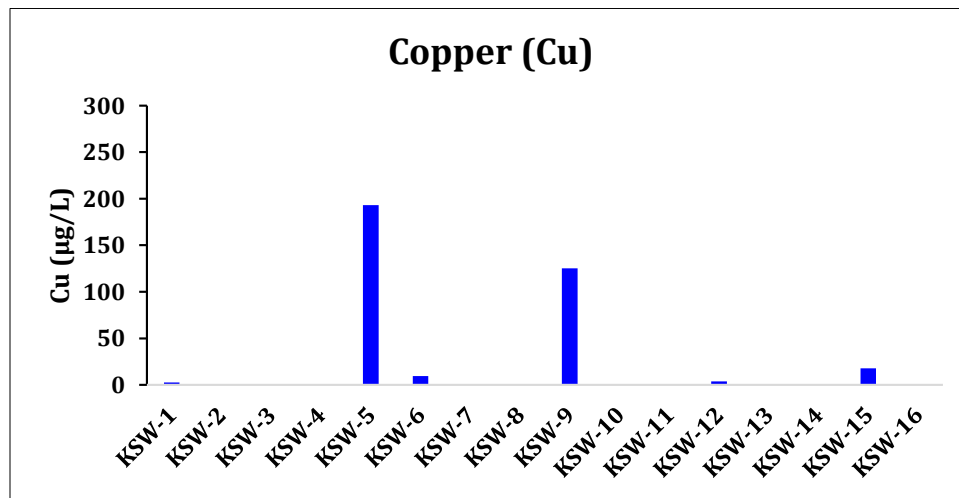


Figure 24: Copper (Cu) concentration ($\mu\text{g/L}$) across the study sampling locations.

As per BIS IS 10500:2012, the acceptable limit for copper in drinking water is $50 \mu\text{g/L}$, with a permissible limit of $1,500 \mu\text{g/L}$ in the absence of an alternate source. The results indicate that most natural surface waters remain within the acceptable limit, while localized exceedances occur at polluted surface water locations, which are not used for potable supply. Copper concentrations in operational waters remain well within CPCB effluent discharge limits, confirming regulatory compliance. Overall, copper enrichment



in the study area is localized, process-related, and effectively managed, with no evidence of off-site contamination or ecological risk.

Barium (Ba)

Barium (Ba) is a naturally occurring alkaline earth metal commonly associated with barite ($BaSO_4$) and carbonate minerals, and it enters surface waters primarily through rock weathering, soil erosion, and groundwater-surface water interaction. Anthropogenic sources of barium include coal combustion residues, drilling fluids, and industrial effluents, although its mobility in water is generally limited due to the low solubility of barium sulphate. At elevated concentrations, barium may affect the cardiovascular and nervous systems, necessitating monitoring in drinking water sources.

In the NTPC Khargone study area, barium concentrations in surface water samples collected during the pre-monsoon season show moderate variability, with values ranging from ~19 to 249 $\mu\text{g/L}$. Lower concentrations are observed in riverine and raw water sources, whereas relatively higher values occur at polluted and operational surface waters, particularly KSW-9 (~249 $\mu\text{g/L}$), KSW-8 (~164 $\mu\text{g/L}$), and KSW-5 (~155 $\mu\text{g/L}$). These elevated concentrations are attributed to geogenic contributions combined with evaporative concentration and ash-water interaction, rather than direct industrial discharge.

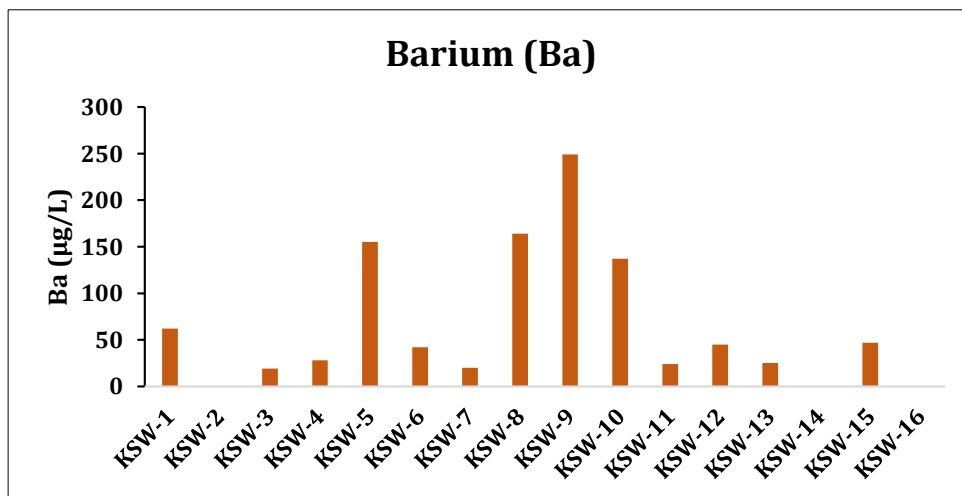


Figure 25: Barium (Ba) concentration ($\mu\text{g/L}$) across the study sampling locations.



According to WHO guidelines, the permissible limit for barium in drinking water is 700 µg/L, while BIS IS 10500:2012 prescribes an acceptable limit of 700 µg/L. All analysed surface water samples, including those showing higher barium concentrations, remain well within the prescribed limits, confirming full regulatory compliance. The spatial distribution of barium does not indicate any progressive enrichment or off-site transport, and concentrations are primarily governed by natural lithological controls. Overall, barium levels in surface waters around NTPC Khargone pose no environmental or human health concern, and the observed variations reflect natural geochemical background with minor operational influence.

5.4.7 Synthesis of Trace Metals in Surface Water

The spatial distribution of trace metals in surface waters around the NTPC Khargone area shows a distinct zone-wise pattern, reflecting differences in land use, hydrological setting, and degree of anthropogenic influence. For interpretation, the study area surface waters were grouped into three functional zones: (i) natural surface waters (rivers and reservoirs), (ii) village ponds and semi-stagnant waters, and (iii) polluted or operational surface waters associated with industrial use and cooling activities (**Table 2**).

Natural surface waters, including riverine and reservoir sources, generally exhibit low concentrations of trace metals that closely reflect regional geogenic background levels. Metals such as arsenic, chromium, cadmium, mercury, nickel, copper, zinc, and barium are mostly present at trace or near-detection levels, and iron concentrations, although occasionally exceeding aesthetic limits, are geogenic in origin and not indicative of pollution. These waters largely comply with BIS and WHO drinking water standards, confirming their suitability for designated uses and absence of metal-related health risks.

Village ponds and semi-stagnant surface waters display moderate enrichment of selected metals, particularly iron, zinc, lead, and copper, with localized elevation of arsenic, mercury, and nickel at a few sites. This enrichment is attributed to domestic wastewater inflow, agricultural runoff, organic matter accumulation, religious activities, and prolonged residence time, rather than direct industrial discharge. Although certain





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parameters marginally exceed BIS acceptable limits at isolated locations (e.g., Fe, Pb, Hg), these waters are not used for potable supply, and the observed concentrations remain well below CPCB effluent standards, indicating localized, non-propagating impacts.

Polluted and operational surface waters, including post-cooling waters and reused industrial waters, show the highest concentrations of trace metals, notably Ni, Cu, Zn, Pb, As, and Fe. These elevated levels are associated with coal combustion residues, ash-water interaction, evaporative concentration, and repeated reuse cycles under zero-liquid-discharge (ZLD) systems. Importantly, even in these waters, metal concentrations remain within CPCB effluent discharge limits, and strict containment ensures no migration into surrounding natural surface waters. Thus, metal enrichment in this zone is process-related, spatially restricted, and effectively managed.

Overall, the zone-wise analysis demonstrates that trace metal contamination is neither widespread nor progressive, and elevated concentrations are confined to specific zones with identifiable sources, without posing off-site environmental or public health risks.

5.4.8 Integrated Synthesis of Major Ions and Trace Metals with Regulatory Compliance

The combined evaluation of major ions and trace metals in surface waters of the NTPC Khargone study area indicates a chemically stable freshwater system, predominantly governed by natural hydrogeochemical processes with localized anthropogenic influence. Major ion chemistry is characterized by Ca–Na–HCO₃ dominance, moderate hardness, low salinity, and fresh-water total dissolved solids, reflecting carbonate buffering, silicate weathering, and seasonal concentration effects under pre-monsoon low-flow conditions.

All major physico-chemical parameters, including pH, EC, TDS, hardness, chloride, sulphate, nitrate, fluoride, and nutrients, remain within BIS, WHO, and CPCB guideline limits for their respective designated uses. Localized increases in sulphate and fluoride in operational waters are associated with ash handling and reuse systems, yet remain fully compliant with effluent discharge standards and do not influence surrounding natural waters.





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Trace metals, when evaluated alongside major ions, show no evidence of systemic contamination or cumulative degradation. Most metals occur at trace to low concentrations, consistent with geogenic background levels. Exceedances of drinking water guideline values are limited to isolated pond or operational locations, and these waters are not intended for potable use. Importantly, all trace metals remain within CPCB effluent standards, and the adoption of ZLD and recirculation practices ensures regulatory compliance and environmental protection.

The integrated chemical signature—supported by Piper and Gibbs plot interpretations—confirms that surface water chemistry is controlled primarily by rock–water interaction, evaporation, and limited anthropogenic inputs, rather than industrial contamination. Nutrient levels remain low, dissolved oxygen is generally adequate, and no eutrophication or metal toxicity risk is evident.





6 GROUNDWATER HYDROLOGY

6.1 Background

Groundwater constitutes a critical component of the regional water resource system in the NTPC Khargone study area, supporting domestic supply, agriculture, and industrial requirements under semi-arid climatic conditions. Understanding the hydrogeological framework, groundwater flow regime, and water quality characteristics is therefore essential for evaluating both baseline conditions and potential impacts associated with thermal power plant operations, particularly with respect to ash-handling facilities and sustained groundwater abstraction.

To characterize the groundwater hydrogeology of the study area, systematic groundwater-level monitoring and water-quality sampling were conducted during the pre-monsoon season of 2025. The investigation covered locations within a 10 km radial buffer of the NTPC Khargone Thermal Power Plant, including piezometers installed around the ash dyke, the plant premises, and surrounding villages, as well as existing dug wells and bore wells used for domestic and agricultural purposes.

In order to assess the aquifer characteristics and potential impacts of groundwater abstraction associated with plant operations, aquifer performance tests (APT) were conducted by the National Institute of Hydrology **(NIH-2018)⁴**, Roorkee, using newly installed exploration and observation wells in the ash pond area. The test results indicate that the aquifer system in the study area exhibits low transmissivity, with an average aquifer transmissivity of 6.55 m²/d and a storage coefficient of 3.61 x 10⁻². The pump test data indicate that the aquifers in the ash pond area of Khargone STPP exhibit low transmissivity and storage coefficients.

Within the 10-km buffer zone, higher water levels are observed in the southern and south-eastern sectors near Kedi Bujurg, Umariya, and Padiliya, where contours reach approximately 255–260 m amsl. In contrast, comparatively lower heads (≈185–205 m

⁴Hydro-geological study for Khargone super thermal power project, Madhya Pradesh, NTPC Limited, Khargone, Madhya Pradesh by NIH (2018)





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amsl) occur toward the northern and north-western parts, including Loundi, Kanapur, and Bhatiyani Khurd.

Accordingly, the regional groundwater flow is predominantly from the south and southeast toward the north and northwest, passing through the NTPC plant and township area. Localized curvature and closed contours near Kedi Bujurg and Kanapur indicate minor groundwater mounds or depressions, suggesting the influence of topography, recharge variability, and possible anthropogenic controls such as ash-dyke storage and surface-water management structures. In view of this flow pattern, and considering the potential migration pathways of dissolved constituents, greater emphasis has been placed on monitoring groundwater conditions along the northern and north-eastern margins of the NTPC Khargone plant area, which constitute the principal downgradient zone.

Table 9: Groundwater-level data (m bgl and m amsl) of monitoring wells in the study area

S.No.	Code	Lat	Long	Source	Elevation (m)	WL(m bgl)	WL(m amsl)
1	KGW-01	22.1156	75.8675	DW	199.66	5.8	193.86
2	KGW-02	22.1241	75.8951	DW	189.72	4.3	185.42
3	KGW-03	22.1225	75.8426	HP	186	4	182
4	KGW-04	22.1232	75.7963	DW	187.89	5.25	182.64
5	KGW-05	22.0449	75.8784	DW	273.14	7.6	265.54
6	KGW-06	22.0764	75.9235	BW	231.4	8.1	223.3
7	KGW-07	22.0281	75.8958	DW	249.95	3.5	246.45
8	KGW-08	22.0631	75.8526	DW	244.6	4.6	240
9	KGW-09	22.0783	75.8367	PZ	238.1	4.7	233.4
10	KGW-10	22.0772	75.8331	PZ	237.59	15.4	222.19
11	KGW-11	22.0745	75.8318	PZ	233.37	3.52	229.85
12	KGW-12	22.0273	75.8324	PZ	231.288	2.5	228.788
13	KGW-13	22.0705	75.8328	PZ	236.711		236.711
14	KGW-14	22.0708	75.8355	PZ	237.5	4.6	232.9
15	KGW-15	22.0087	75.9093	BW	244.2	4.1	240.1
16	KGW-16	21.9956	75.8578	HP	242.42	3	239.42
17	KGW-17	22.1089	75.9355	DW	200.5	2.52	197.98
18	KGW-19	22.0757	75.861	BW	248.5	5.8	242.7
19	KGW-20	22.0622	75.7669	BW	198.84	4.9	193.94



Following the recommendations of NIH experts and previous hydrogeological studies, a dedicated groundwater monitoring network was established and finalized for the study area. This network comprises six piezometers installed around the ash dyke, plant premises, and township area for long-term monitoring of groundwater levels and quality, supplemented by selected existing groundwater abstraction structures in surrounding villages. The spatial distribution of the monitoring network is designed to capture upgradient-downgradient conditions, potential impact zones, and background groundwater quality, and is illustrated in Figure 26.

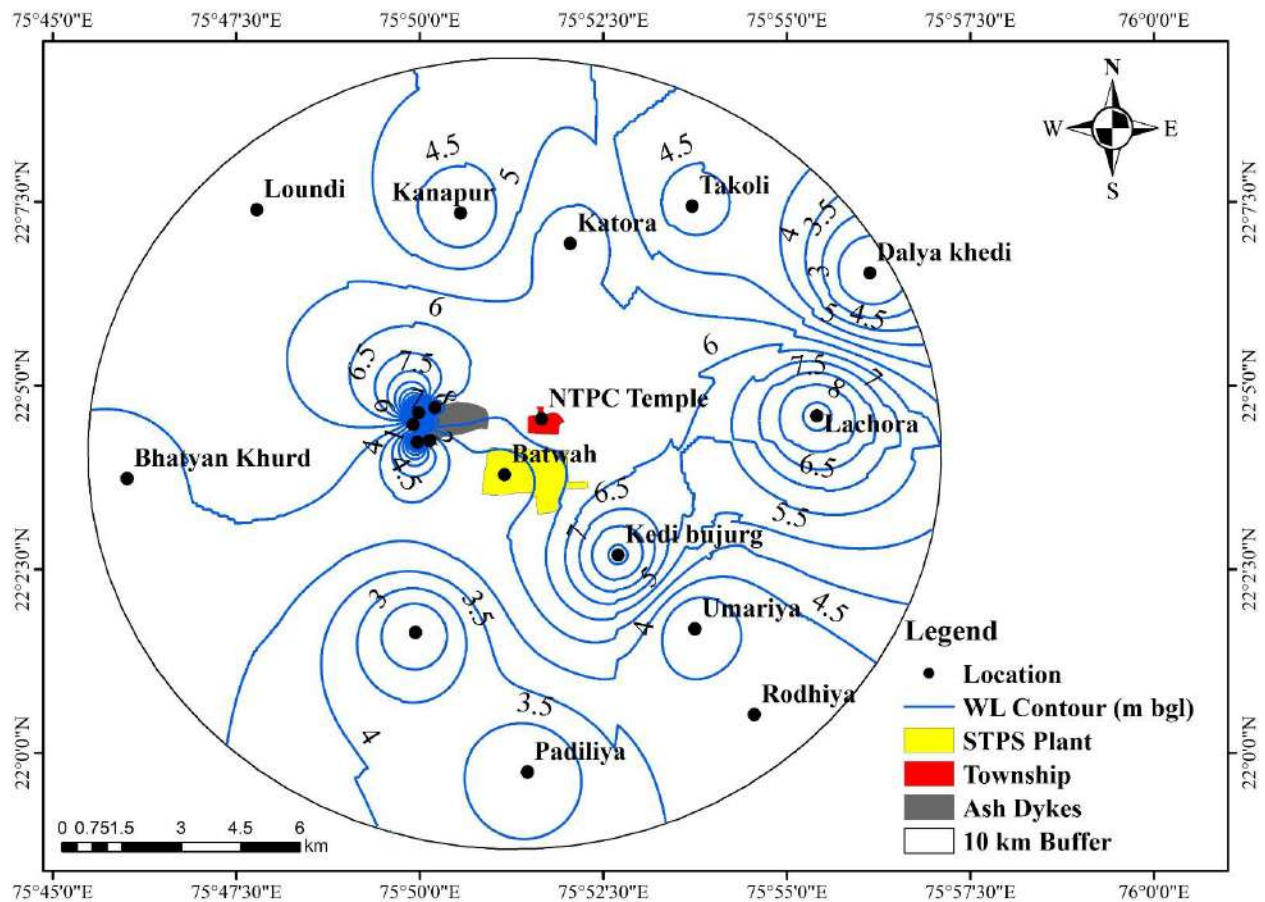


Figure 26: Groundwater depth-to-water-level contour map (m bgl) with flow directions within a 10 km buffer around the study area.

All groundwater samples collected during the pre-monsoon monitoring period were analysed for a comprehensive suite of parameters, including physico-chemical parameters (pH, electrical conductivity, total dissolved solids, and dissolved oxygen), major ions (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , CO_3^{2-} , HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , PO_4^{3-}), and trace/heavy metals (As, Cd, Cr, Hg, Pb, Zn, Fe, Ni, Cu, and Ba). In addition, isotopic analyses were carried out to support the interpretation of groundwater origin, recharge characteristics, and flow dynamics.

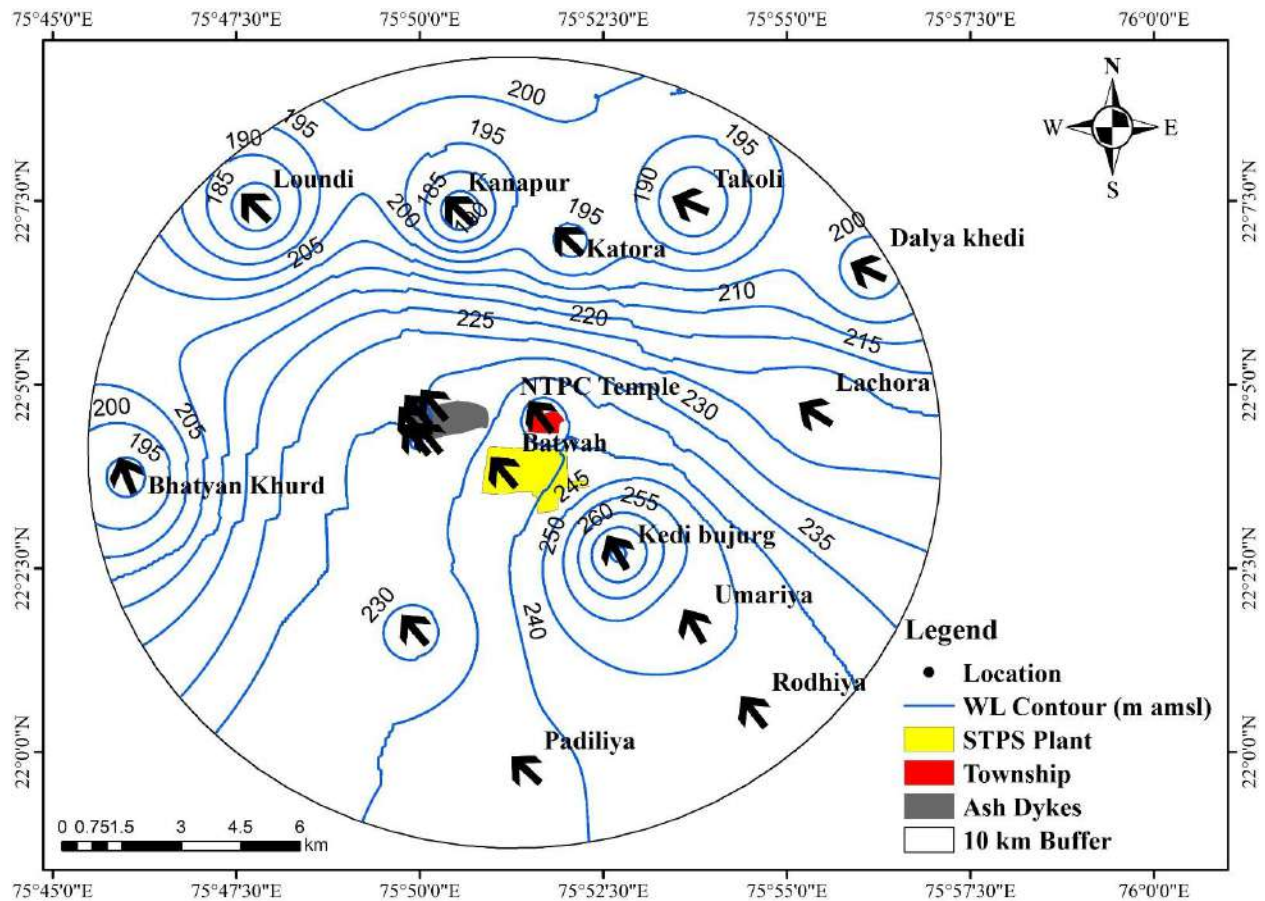


Figure 27: Groundwater water-level contour map (m amsl) with flow directions within a 10 km buffer around the study area.

The integrated groundwater investigation presented in this chapter provides the basis for evaluating hydrogeochemical processes, assessing compliance with BIS/WHO



drinking water standards, and identifying any localized influence of ash disposal or industrial activity, thereby supporting a scientifically robust assessment of groundwater sustainability and environmental safety in the NTPC Khargone study area.

6.2 Hydrogeological scenario

6.2.1 Aquifers and their characteristics

The hydrogeological framework of Khargone (West Nimar) district is primarily controlled by Deccan Trap basaltic formations, their weathered and fractured horizons, and limited occurrences of alluvial deposits along the Narmada River and its tributaries. Based on regional geology, geomorphological setting, and groundwater potential as documented in Central Ground Water Board (CGWB) reports, the district can be broadly classified into the following hydrogeological units:

- **Alluvial Aquifer (Quaternary deposits along river valleys)**
- **Weathered Basalt Aquifer**
- **Fractured Basalt Aquifer (Consolidated Formation – Deccan Traps)**

Alluvial Aquifer

The alluvial aquifers are restricted to the Narmada River floodplain and narrow stretches along major tributaries, consisting of sand, gravel, silt, and clay of Quaternary age. These aquifers generally occur under unconfined to semi-confined conditions and exhibit moderate to good groundwater potential due to high porosity and permeability. Tube wells constructed in alluvial zones typically tap depths of 20–40 m bgl and yield 20–40 m³/hr, depending on the thickness and grain size distribution of the deposits. Groundwater recharge in these areas is primarily governed by river seepage, monsoonal rainfall, and irrigation return flow.

Weathered Basalt Aquifer

The weathered zone of Deccan Trap basalts, developed due to prolonged chemical and mechanical weathering, forms an important shallow aquifer across much of the district.





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The thickness of the weathered mantle generally varies from 5 to 20 m, though localized thickening is observed in valley portions and gentle slopes. Groundwater in this zone occurs under unconfined conditions and is tapped mainly through dug wells and shallow bore wells, with typical yields ranging from 5 to 15 m³/hr. The groundwater potential of this zone is moderate and highly variable, controlled by degree of weathering, joint density, and topography.

Fractured Basalt Aquifer

The fractured and jointed basaltic formations constitute the principal deeper aquifer system in Khargone district. Groundwater occurs in secondary porosity zones, developed along cooling joints, columnar fractures, vesicular horizons, and inter-flow contacts. These aquifers generally occur under semi-confined to confined conditions at depths ranging from 40 to 150 m bgl. CGWB exploratory drilling and regional hydrogeological investigations indicate the presence of multiple fracture zones, typically encountered at depths of 30–40 m, 60–80 m, and occasionally below 100 m. Bore wells tapping productive fracture zones yield 20–60 m³/hr, while yields up to 80–100 m³/hr have been reported locally where thick vesicular or highly fractured basalt is encountered.

Hydraulic properties of the fractured basalt aquifer show moderate transmissivity, generally ranging from 20 to 500 m²/day, depending on fracture connectivity and saturated thickness. Storativity values indicate semi-confined to confined behavior, with groundwater movement largely controlled by structural features and inter-flow zones rather than primary porosity.

6.2.2 Groundwater Occurrence and Flow Regime

Groundwater in the shallow aquifer system (alluvium and weathered basalt) occurs under unconfined conditions, while deeper fractured basalt aquifers exhibit semi-confined to confined conditions. Based on CGWB assessments and site-specific investigations in the NTPC Khargone area, the regional groundwater flow direction generally follows the topographic gradient toward the Narmada River, with local variations influenced by drainage, pumping stress, and subsurface structural controls.





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In the immediate project area, groundwater flow is observed to be from south-east toward the north-north-west, consistent with the regional slope and river alignment.

6.2.3 Implications for the NTPC Khargone Area

The presence of multi-layered basaltic aquifers with moderate transmissivity and storage suggests that the groundwater system has reasonable buffering capacity, provided abstraction remains within sustainable limits. The installation of piezometers around the ash dyke and plant premises is therefore critical for monitoring groundwater-level fluctuations and detecting potential changes in groundwater quality along downgradient flow paths.

Overall, CGWB assessments indicate a basalt-dominated aquifer system in the Khargone district, with localized alluvial potential, moderate groundwater availability, and a strong dependence on monsoonal recharge, necessitating careful groundwater management and continuous monitoring in industrialized areas such as the NTPC Khargone Thermal Power Plant.

6.3 Groundwater Level Measurement

Groundwater level monitoring was carried out during the pre-monsoon season of 2025 (April–May 2025) to assess the depth to the water table, spatial variation, and groundwater flow behaviour in and around the NTPC Khargone Thermal Power Plant and ash disposal area. Water levels were measured in 20 groundwater abstraction structures, comprising hand pumps, bore wells, dug wells, and piezometers, located within a 10 km radius of the plant premises, with special emphasis on wells installed around the ash dyke and downgradient areas.

The observed depth to the water table during the pre-monsoon period shows noticeable spatial variability across the study area. Groundwater levels were deepest in village areas located away from the Narmada River and major drainage courses, reflecting reduced recharge and sustained groundwater abstraction. The maximum depth to water table, of about 17–18 m below ground level (mbgl), was recorded in parts of the upland village areas, while comparatively shallow groundwater levels, ranging from 6 to 8 mbgl, were observed in the northern and north-eastern sectors of the ash pond and plant area,





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particularly near piezometer locations installed in low-lying terrain. This shallow water table is attributed to topographic control, localized recharge, and proximity to drainage features.

Overall, during the pre-monsoon 2025, the depth to the groundwater table in the study area varied from approximately 6.5 mbgl to 17.7 mbgl, indicating moderate seasonal drawdown typical of basaltic aquifer systems in the Narmada basin under pre-monsoon conditions. Based on the measured water levels, a depth-to-water table map for the pre-monsoon season was prepared for the study area, covering the ash pond, plant premises, and surrounding buffer zone, and is presented in (Figure 26). When referenced to mean sea level (msl), the groundwater elevation in the study area during the pre-monsoon 2025 period ranges from approximately 150 m to 260 m above mean sea level (amsl) (exact values depend on local ground elevation). The configuration of the groundwater table closely follows the regional topographic gradient, confirming the strong influence of surface morphology on groundwater movement in the basaltic terrain.

Interpretation of groundwater elevation contours indicates that the general direction of groundwater flow is towards the Narmada River, which acts as the principal regional discharge zone. Locally, groundwater flow is observed to be from south-east to north-west and northward, consistent with the slope of the land surface and drainage pattern, as depicted in the groundwater flow direction map (Figure 27). The observed flow regime corroborates the findings of aquifer performance tests and earlier hydrogeological assessments, and supports the selection of downgradient monitoring locations north and north-east of the NTPC Khargone plant area.

Overall, the groundwater level data indicate that the aquifer system in the study area exhibits no abnormal drawdown or cone of depression associated with plant operations during the pre-monsoon period. The groundwater regime remains hydraulically stable, with water level variations primarily controlled by topography, lithology, seasonal recharge conditions, and local groundwater abstraction, rather than by ash disposal or industrial activity.





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6.4 Groundwater Quality

To evaluate the groundwater quality in and around the NTPC Khargone Thermal Power Plant and within the 10 km radial buffer zone, a total of 19 groundwater samples were collected during the pre-monsoon season of 2025 (April–May 2025). The samples were drawn from piezometers installed around the ash dyke and plant premises, as well as from hand pumps and bore wells in surrounding villages, representing both potentially impacted and background groundwater conditions. All collected samples were analysed for physico-chemical parameters (pH, electrical conductivity, total dissolved solids, and dissolved oxygen), major ions (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , HCO_3^- , Cl^- , SO_4^{2-} , NO_3^-), and trace metals, in accordance with standard analytical protocols. The results of physicochemical analysis, as summarized in the updated **Table 10**, are discussed below.





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Table 10: Physico-chemical parameters and Major ions of Ground Water in the buffer area during Pre-Monsoon 2025

S.No.	GCS Code	pH	EC	TDS	DO	Temp	Na	k	Ca	Mg	CO3	HCO3	Cl	F	SO4	NO3	PO4
1	KGW-1	8.2	644	460	3.7	28.7	45.4	1.6	55.0	8.9	ND	133	47.0	0.47	122	0.3	0.00
2	KGW-2	8.0	714	510	5	27.5	62.1	2.0	70.5	19.9	ND	402	43	0.62	25.6	4.6	0.00
3	KGW-3	7.6	1218	870	6	28.9	106.0	9.8	44.9	25.5	ND	461	74.6	0.51	54.1	15.7	0.00
4	KGW-4	7.8	714	510	1.8	28.9	48.3	1.8	109.8	34.4	ND	465	44.0	0.42	36	42.4	0.01
5	KGW-5	7.4	966	690	4.8	27.8	45.8	2.6	72.0	34.5	ND	453	49	0.65	43.0	38.0	0.00
6	KGW-6	8.1	560	400	2.5	27.9	66.4	1.2	52.2	27.6	ND	315	43.7	0.82	21.3	4.7	0.01
7	KGW-7	7.4	1372	980	5.5	24.8	90.7	3.8	64.7	34.3	ND	424	67.8	0.32	32.5	28	0.13
8	KGW-8	7.9	1092	780	4.9	34.3	42.7	1.1	85.0	43.6	ND	442	46.5	0.60	107.5	3.6	0.01
9	KGW-9	7.8	1274	910	2.4	28.2	53.0	2.5	68.0	46.7	ND	390	42	0.95	56	1.1	0.00
10	KGW-10	7.7	1834	1310	3.6	28	56.4	1.6	97.1	40.1	ND	328	44	0.86	195.6	1.5	0.00
11	KGW-11	7.9	1708	1220	5.4	28.6	54.1	1.9	104.4	29.1	ND	206	51	0.76	199	0.8	0.00
12	KGW-12	8.8	196	140	6	31	27.2	3.1	61.6	23.7	5.5	205	36	0.92	87	1.3	0.00
13	KGW-13	8.2	1736	1240	7.4	29.2	96.4	2.3	139.2	30.9	ND	381	83	0.77	230.1	1.6	0.04
14	KGW-14	8.0	840	600	3.9	29.2	53.4	1.9	92.7	44.7	ND	289	55.7	0.87	267	1.7	0.00
15	KGW-15	7.6	1288	920	5.6	26.6	84.1	1.8	63.6	41.9	ND	575	65.5	0.23	39.2	13	0.00
16	KGW-16	7.6	812	580	4.2	27.8	35.3	1.7	68.9	39.3	ND	441	38.0	0.62	28.9	3.2	0.00
17	KGW-17	8.2	910	650	4.9	25.7	84.8	2.6	70.6	37.9	ND	464	64.2	0.39	19	15	0.00
18	KGW-18	7.6	1025	732	3.6	27.8	53.8	1.8	50.5	23.9	ND	342	42	0.52	23.2	13.9	0.01
19	KGW-19	8.9	1204	860	4.5	28.2	49.5	1.3	44.8	21.1	9.4	311	37.3	0.29	24.3	3.7	0.05





6.4.1 pH, EC, TDS

A perusal of the hydrochemical data indicates that groundwater in the study area is predominantly mildly alkaline in nature. During the pre-monsoon 2025 period, pH values range from 7.4 to 8.9, with most samples clustering between 7.6 and 8.2, reflecting effective carbonate–bicarbonate buffering in the basaltic aquifer system. Slightly higher pH values (≥ 8.5) are observed at a few locations, notably KGW-12 and KGW-19, which may be attributed to longer groundwater residence time, enhanced water–rock interaction, and lower recharge during the pre-monsoon period. All measured pH values fall well within the BIS IS 10500:2012 acceptable range (6.5–8.5) for drinking water, with marginal exceedances at isolated locations that have no practical implications, as these waters are not used directly for potable supply.

Electrical conductivity (EC) values exhibit moderate spatial variability, reflecting differences in aquifer depth, lithology, and local land use. EC values range from 196 $\mu\text{S}/\text{cm}$ (KGW-12) to 1960 $\mu\text{S}/\text{cm}$ (KGW-10). Groundwater samples collected from piezometers around the ash dyke generally exhibit higher EC values than those from village wells, indicating relatively higher ionic concentrations due to greater residence time and evaporative concentration, rather than contamination. Despite this variability, EC values remain within limits typically considered suitable for drinking and irrigation purposes, and no abnormal salinity build-up is observed.

Total dissolved solids (TDS) concentrations in groundwater during the pre-monsoon 2025 period vary from 140 mg/L (KGW-12) to 1310 mg/L (KGW-10). Out of 19 analyzed samples, 15.8% fall below 500 mg/L TDS, 68.4% lie within the 500–1000 mg/L range, and 15.8% exceed 1000 mg/L, indicating overall freshwater dominance with limited occurrence of elevated mineralization. The majority of samples exhibit TDS values between 500 and 900 mg/L, indicating fresh to slightly mineralized groundwater. Based on standard classification, most groundwater samples fall under the “freshwater” category (TDS < 1000 mg/L), with only one or two samples marginally exceeding this threshold. Importantly, all groundwater samples remain well within the BIS permissible limit of 2000 mg/L, confirming their suitability for domestic and other uses from a salinity perspective.

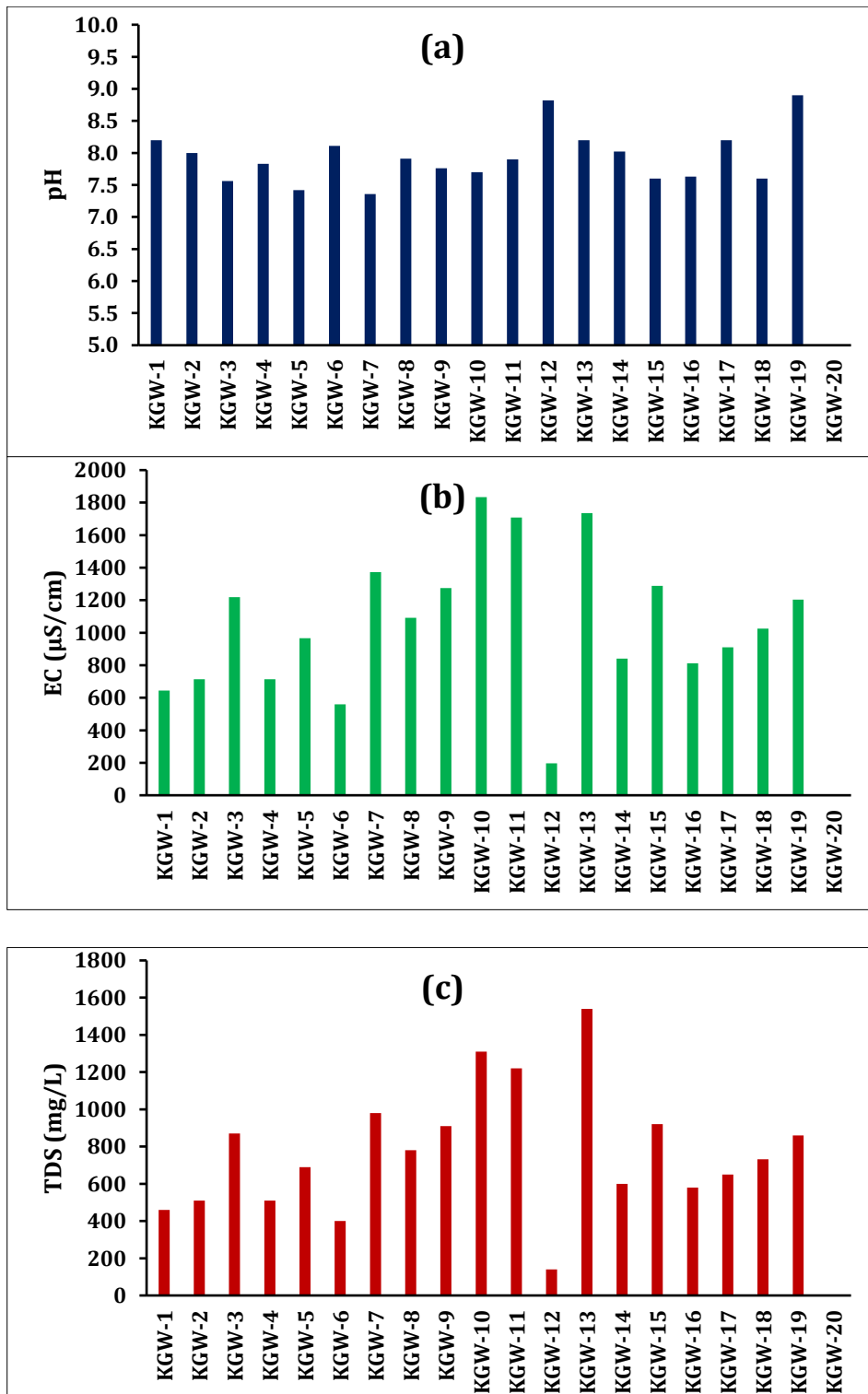


Figure 28: Pre-monsoon Graphical Representation of Physico-chemical parameters (a) pH (b) EC (c) TDS, in surface water samples in the study area.



Table 11: Classification of groundwater based on Total Dissolved Solids, (BIS–USGS Salinity Classification Framework)

TDS (mg/L)	USGS Class	BIS Drinking-Water Status	% Samples (Pre-monsoon)	Hydrogeochemical Interpretation
< 500	Fresh water	Desirable	42.9%	Recharge-dominated, low mineralization.
500 – 1,000	Fresh water	Acceptable/ Permissible	57.1%	Mild mineralization due to water–rock interaction.
1,000 – 2,000	Brackish transition	Permissible limit (only if no alternate source)	Nil	Beginning of salinity build-up.
2,000 – 10,000	Brackish water	Not suitable for drinking	Nil	Evaporation, anthropogenic input, or long residence time.
10,000 – 100,000	Saline water	Unsuitable	Nil	Strong salinization or industrial influence.
> 100,000	Brine	Unsuitable	Nil	Extreme salinity conditions.

The observed distribution of pH, EC, and TDS clearly indicates that groundwater chemistry in the NTPC Khargone area is controlled primarily by natural hydrogeochemical processes, including basalt weathering, dissolution of carbonate minerals, and seasonal concentration effects during pre-monsoon conditions. Slightly elevated EC and TDS values near the ash dyke piezometers do not exhibit any systematic enrichment trend or downgradient increase, suggesting no discernible impact of ash disposal activities on regional groundwater quality. Overall, the physicochemical characteristics of groundwater during the pre-monsoon 2025 monitoring period indicate chemical stability, regulatory compliance, and the absence of salinity- or alkalinity-related concerns in the study area.



6.4.2 Dissolved Oxygen (DO)

Dissolved Oxygen (DO) represents the concentration of molecular oxygen (O₂) present in water and is an important indicator of the redox condition, biological activity, and overall chemical environment of groundwater. Unlike surface water, groundwater typically exhibits lower DO concentrations due to limited direct contact with the atmosphere, longer residence times, and oxygen consumption during microbial oxidation of organic matter and mineral weathering reactions. The DO concentration in groundwater is influenced by factors such as depth of aquifer, recharge rate, temperature, and availability of biodegradable organic matter.

In the NTPC Khargone study area, groundwater samples collected during the pre-monsoon season of 2025 show low to moderate dissolved oxygen concentrations, characteristic of basaltic aquifer systems under pre-monsoon conditions. DO values in groundwater range from approximately 1.8 mg/L to 7.4 mg/L. Lower DO concentrations (≤ 3 mg/L) are observed at a few locations, particularly in piezometers around the ash dyke and in deeper bore wells, which can be attributed to longer groundwater residence time, reduced recharge during the dry season, and oxygen consumption during geochemical reactions. In contrast, relatively higher DO values (≥ 5 mg/L) are recorded in shallow village wells and locations influenced by recent recharge, indicating better aeration and oxic groundwater conditions.

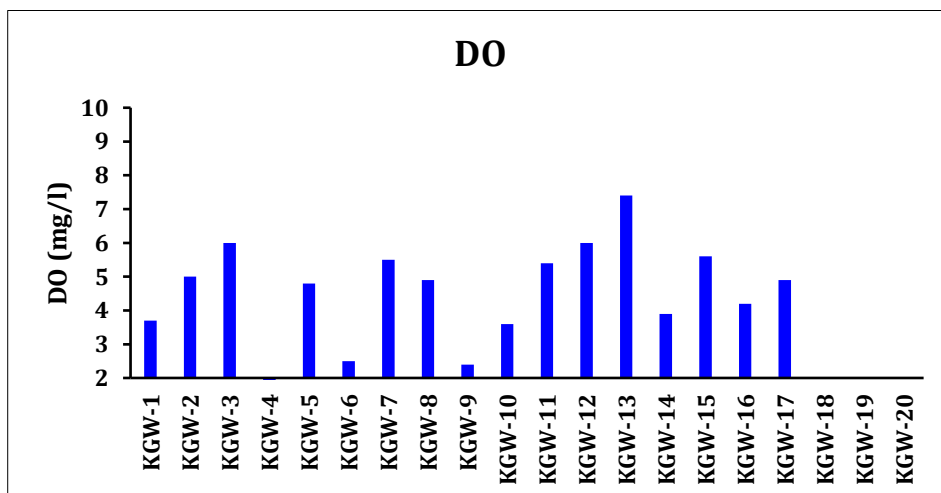


Figure 29: Dissolved oxygen (DO; mg/L) levels in groundwater samples collected from monitoring locations in the study area (pre-monsoon season)

Variation in dissolved oxygen (DO; mg/L) concentrations among groundwater samples collected from different monitoring locations during the pre-monsoon





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season, showing differences in DO levels across the sampled wells. (Figure 29) illustrates that the majority of groundwater samples exhibit oxic to mildly sub-oxic conditions, with no evidence of widespread reducing environments. Such conditions are favorable as they limit the mobilization of redox-sensitive contaminants such as iron, manganese, arsenic, and nitrate.

It is pertinent to note that BIS (IS 10500:2012) and WHO (2011) do not prescribe any guideline value for dissolved oxygen in groundwater intended for drinking or domestic use, as DO does not directly influence potability. The observed DO concentrations in the study area therefore do not pose any health-related concerns and primarily serve as indicators of the natural hydrogeochemical environment. Overall, the dissolved oxygen regime suggests that groundwater in the NTPC Khargone area remains chemically stable, largely oxic, and unaffected by anaerobic pollution processes during the pre-monsoon 2025 period.

6.4.3 Major Cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+)

The major cations in groundwater of the NTPC Khargone study area include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+). Evaluation of the updated hydrochemical dataset (Table 10) indicates that calcium and sodium together dominate the cationic composition, contributing approximately 80–85% of the total cationic charge (TZ^+) in most groundwater samples collected during the pre-monsoon 2025 season. All major cations exhibit pronounced spatial variability, reflecting differences in aquifer depth, lithology, residence time, and localized recharge conditions. The overall order of cation dominance in groundwater is $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$, which is characteristic of basalt-derived groundwater systems influenced by carbonate and silicate weathering.



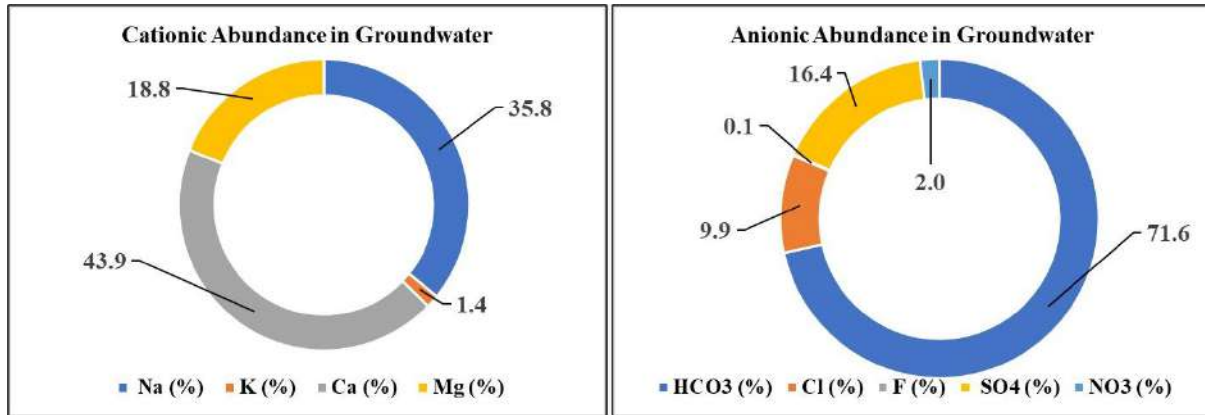


Figure 30: Cationic and Anionic abundance in groundwater samples, showing the relative contribution (%) of Na⁺, K⁺, Ca²⁺, and Mg²⁺. and distribution of HCO₃⁻, Cl⁻, F⁻, SO₄²⁻, and NO₃⁻

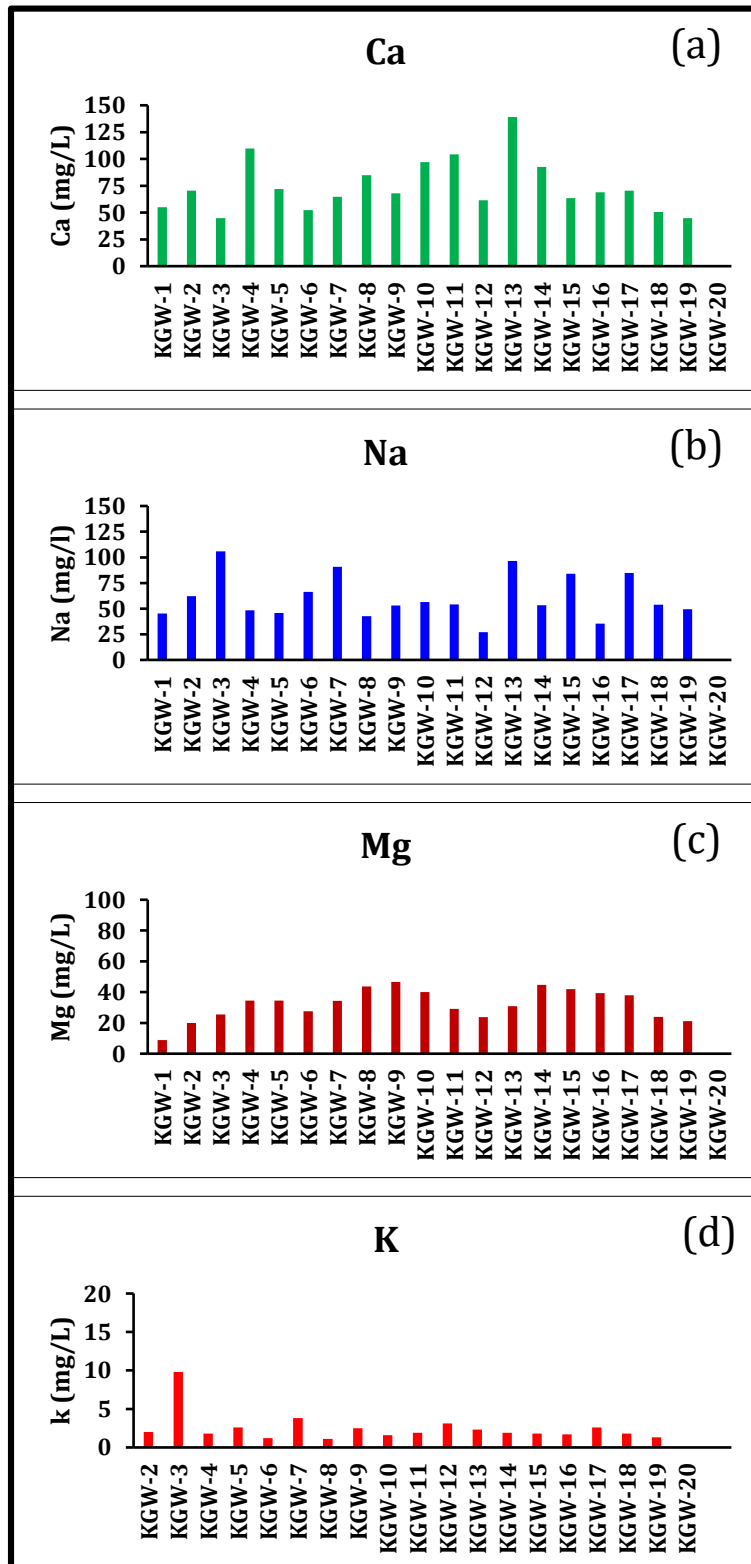


Figure 31: (a) Calcium (b) Sodium (c) Magnesium (d) Potassium Concentrations in groundwater samples collected from monitoring locations KGW-1 to KGW-20 in the study area (pre-monsoon season).



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Calcium (Ca²⁺):

Calcium is the dominant cation in groundwater of the Khargone region, contributing on average ~55–60% of the total cations. Based on the updated dataset (**Table 10**), calcium concentrations range from ~42 mg/L to ~183 mg/L, with an average value of approximately 85–90 mg/L.

Elevated calcium concentrations are particularly observed in piezometers located around the ash dyke (KGW-13, KGW-11) and in deeper village bore wells (KGW-4, KGW-10). These higher values are interpreted as the result of prolonged rock–water interaction within fractured Deccan Trap basalts, dissolution of secondary calcite fillings, and concentration during the pre-monsoon low-recharge period. Shallow groundwater samples closer to surface water bodies and recharge zones show comparatively lower calcium values, reflecting dilution by recent recharge.

From a regulatory perspective, approximately 50% of groundwater samples marginally exceed the BIS acceptable limit of 75 mg/L, but none exceed the permissible limit of 200 mg/L. These exceedances are entirely geogenic and not associated with pollution sources. Elevated calcium contributes to moderate to high hardness, which is an aesthetic issue rather than a health concern. Future prospects indicate that calcium levels may temporarily increase during prolonged dry periods but will remain within regulatory limits.

Sodium (Na⁺):

Sodium concentrations in groundwater vary between ~27 mg/L and ~106 mg/L, with an average value of ~60 mg/L, accounting for ~25–30% of total cations. Higher sodium concentrations are recorded at KGW-3, KGW-7, KGW-13, and KGW-17, predominantly in deeper bore wells and downgradient locations.

The elevated sodium levels are primarily attributed to silicate weathering of feldspars and cation-exchange processes, where calcium in solution is exchanged with sodium adsorbed on clay minerals formed during basalt alteration. In shallow village wells, minor sodium enrichment may also reflect irrigation return flow and infiltration of domestic wastewater, although concentrations remain modest.

Importantly, no groundwater sample exceeds the BIS/WHO guideline value of 200 mg/L, and sodium levels are well within safe limits for drinking and irrigation. There is no spatial correspondence between sodium enrichment and proximity to the ash





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dyke, indicating no industrial impact. Long-term prospects suggest sodium levels may slowly increase with groundwater age but are unlikely to breach regulatory thresholds.

Magnesium (Mg^{2+}):

Magnesium concentrations in groundwater range from ~10 mg/L to ~50 mg/L, with an average concentration of ~25–30 mg/L, contributing ~14–15% of the total cationic balance. Magnesium enrichment is most evident in deep bore wells and piezometers (KGW-9, KGW-14, KGW-15), reflecting weathering of ferromagnesian minerals (pyroxenes and olivine) typical of basaltic lithology.

Three locations (KGW-7, KGW-18, and PZ-1) slightly exceed the BIS acceptable limit of 30 mg/L, though all remain well below the permissible limit of 100 mg/L. These anomalies are interpreted as natural geochemical signatures associated with deeper aquifer zones and longer groundwater residence times. There is no evidence linking magnesium enrichment to surface contamination or industrial activities.

From a groundwater quality standpoint, elevated magnesium enhances permanent hardness but does not pose any health risk. Continued monitoring is advisable in deeper aquifers, particularly during extended dry years, to track concentration effects.

Potassium (K^+)

Potassium occurs at very low concentrations, ranging from ~0.8 mg/L to ~3.8 mg/L, with an average of ~1.5–2.0 mg/L, contributing ~1% of total cations. The consistently low potassium levels across all samples reflect strong fixation in clay minerals, resistance of potassium-bearing minerals to weathering, and rapid adsorption onto soil particles.

Slightly higher potassium values observed in a few village wells (KGW-3, KGW-7) may be linked to agricultural fertilizer use and surface water recharge, but these variations are minor and localized. Since BIS and WHO have not specified guideline limits for potassium and observed concentrations are geochemically normal, potassium poses no groundwater-quality concern.

Overall, the major cation chemistry of groundwater in the NTPC Khargone study area indicates a calcium–sodium dominated hydrochemical regime, controlled largely by basalt weathering, carbonate dissolution, and residence time effects, with no





evidence of abnormal cation enrichment or industrial contamination. All major cations remain within BIS/WHO permissible limits, confirming that groundwater quality is chemically stable and suitable for drinking and other domestic uses during the pre-monsoon 2025 period.

6.4.4 Major Anions (HCO_3^- & CO_3^{2-} , Cl^- , SO_4^{2-} , NO_3^- , F^- and PO_4^{2-})

The anion chemistry of the groundwater samples analysed during the pre-monsoon season (May 2025) indicates that bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), nitrate (NO_3^-), and fluoride (F^-) are the dominant anionic constituents across most sampling locations. Among these, bicarbonate is the principal anion, reflecting extensive rock–water interaction, soil CO_2 contribution, and carbonate–silicate weathering processes within the basaltic aquifer system of the Khargone region. The overall abundance pattern of anions in groundwater follows the order: $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^- > \text{NO}_3^- > \text{F}^- > \text{PO}_4^{3-}$ (Figure 30).

This sequence indicates a groundwater system primarily controlled by geogenic processes, particularly basalt weathering and residence-time–driven chemical evolution, with secondary contributions from anthropogenic sources in localized shallow aquifers. Elevated bicarbonate and sulphate concentrations are generally associated with deeper bore wells and piezometers, suggesting prolonged groundwater circulation and concentration effects during the pre-monsoon period. In contrast, chloride and nitrate exhibit relatively higher variability in shallow village wells, indicating potential domestic wastewater infiltration, agricultural activities, and irrigation return flow. Fluoride occurs at lower concentrations overall but exhibits localized enrichment in deeper, alkaline, bicarbonate-rich groundwater zones, consistent with geogenic mobilization mechanisms.

Bicarbonate (HCO_3^-)

Bicarbonate is the dominant anion in groundwater of the NTPC Khargone region and reflects the combined effects of soil CO_2 dissolution, carbonic acid weathering, and prolonged interaction with basaltic aquifers of the Deccan Trap province. In the study area, bicarbonate concentrations range from approximately 133 to 575 mg/L, with an average of 380–420 mg/L, accounting for 65–70% of the total anionic charge (TZ).



Higher bicarbonate concentrations are observed in deeper bore wells and piezometers (e.g., KGW-15, KGW-3, KGW-5), where groundwater residence time is longer and water has undergone extensive silicate weathering and carbonate buffering. Shallow village wells influenced by surface recharge show comparatively lower bicarbonate values. Seasonal concentration during the pre-monsoon period further enhances bicarbonate levels due to reduced dilution and increased evaporation.

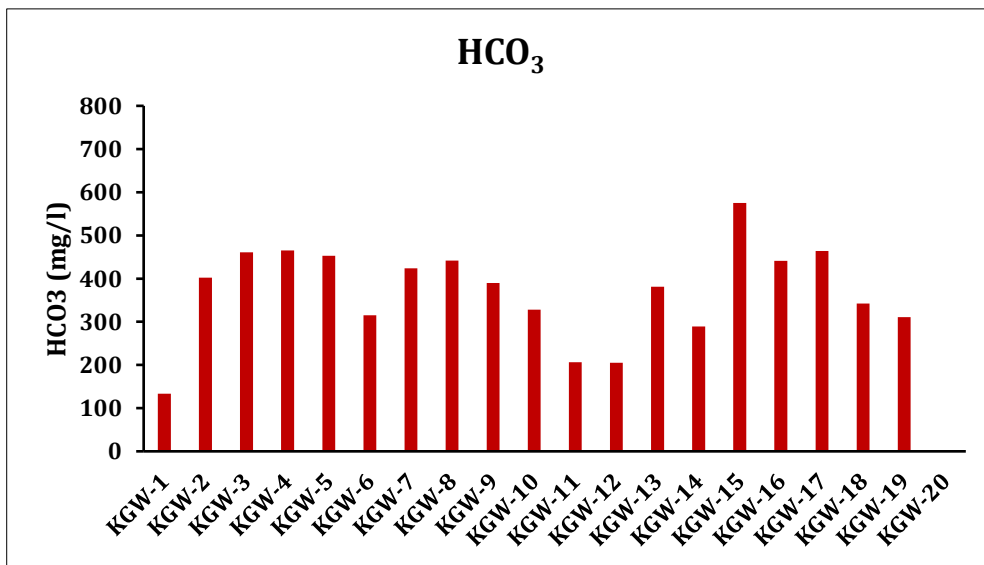


Figure 32: Bicarbonate (HCO_3^-) concentration in groundwater during the pre-monsoon period.

From a regulatory standpoint, most samples remain within the BIS acceptable limit of 200 mg/L, while several deeper groundwater samples exceed this threshold but remain below the permissible limit of 600 mg/L. These exceedances are geogenic and non-polluting, contributing mainly to alkalinity and buffering capacity, with no adverse health implications.





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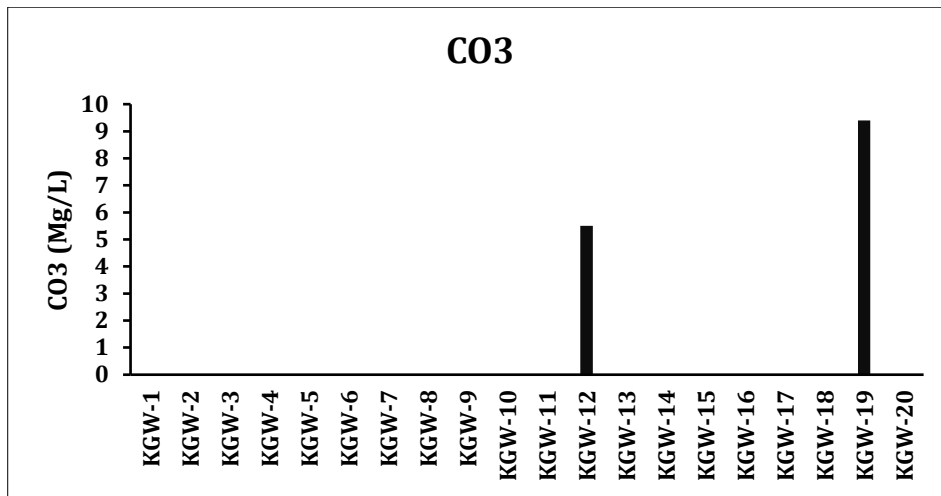


Figure 33: Carbonate (CO₃⁻) concentration (mg/L) across the study sampling locations.

Chloride (Cl⁻)

Chloride behaves as a conservative tracer and is useful for identifying anthropogenic influence. In the Khargone groundwater samples, chloride concentrations range from ~36 mg/L to ~83 mg/L, with an average of ~50–55 mg/L, indicating low to moderate salinity.

Slightly elevated chloride values are observed in village-based wells (KGW-13, KGW-15, KGW-7) where groundwater is shallow and susceptible to domestic wastewater seepage, cattle waste, and irrigation return flow.

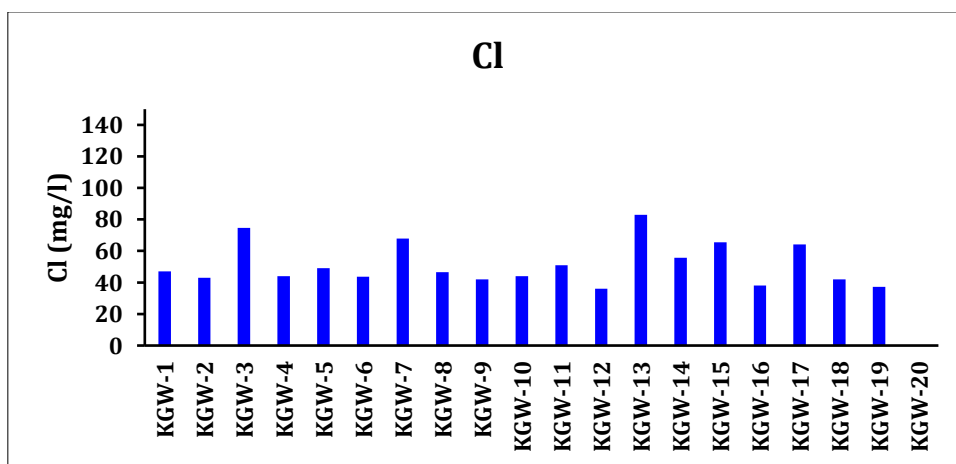


Figure 34: Chloride (Cl⁻) concentration (mg/L) across the study sampling locations.





All groundwater samples are well within BIS and WHO guideline values (250 mg/L), indicating excellent compliance. Future projections suggest that chloride may increase marginally in shallow aquifers under intensified land use, warranting periodic monitoring.

Sulphate (SO₄²⁻)

Sulphate concentrations in groundwater range from ~19 mg/L to ~330 mg/L, with an average concentration of approximately 90–120 mg/L. Sulphate originates from oxidation of sulphide minerals, dissolution of gypsum traces, fertilizer inputs, and atmospheric deposition.

Higher sulphate values are observed in deeper groundwater samples and downgradient locations (KGW-14, KGW-10), indicating longer residence time and concentration effects during the pre-monsoon season. Importantly, groundwater near the ash dyke does not show consistent sulphate enrichment, suggesting effective containment of ash disposal facilities.

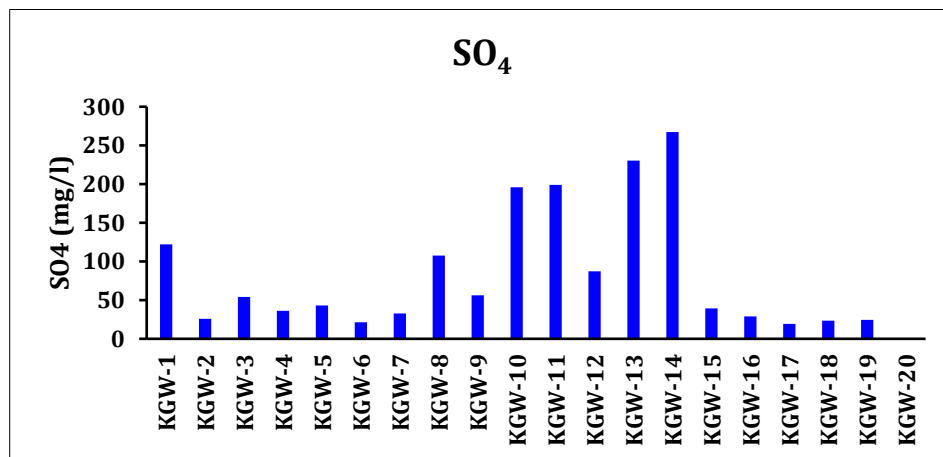


Figure 35: Sulphate (SO₄⁻) concentration (mg/L) across the study sampling locations.

All sulphate concentrations remain within the BIS acceptable (200 mg/L) and permissible (400 mg/L) limits, confirming compliance. Elevated sulphate contributes to temporary salinity and taste issues but does not pose a health risk at observed levels.





Nitrate (NO_3^-)

Nitrate is a key indicator of anthropogenic contamination in groundwater. In the Khargone study area, nitrate concentrations range from ~0.3 mg/L to ~42.4 mg/L, with an average of approximately 12–15 mg/L.

Higher nitrate concentrations are recorded in shallow village wells (KGW-4, KGW-5, KGW-7), reflecting fertilizer application, domestic sewage leakage, and animal waste. Deeper bore wells and piezometers generally show lower nitrate levels due to denitrification and longer residence times.

All groundwater samples remain below the BIS/WHO maximum permissible limit of 45 mg/L, indicating no immediate health risk. However, localized high-nitrate zones highlight the need for nutrient management and sanitation improvements in villages.

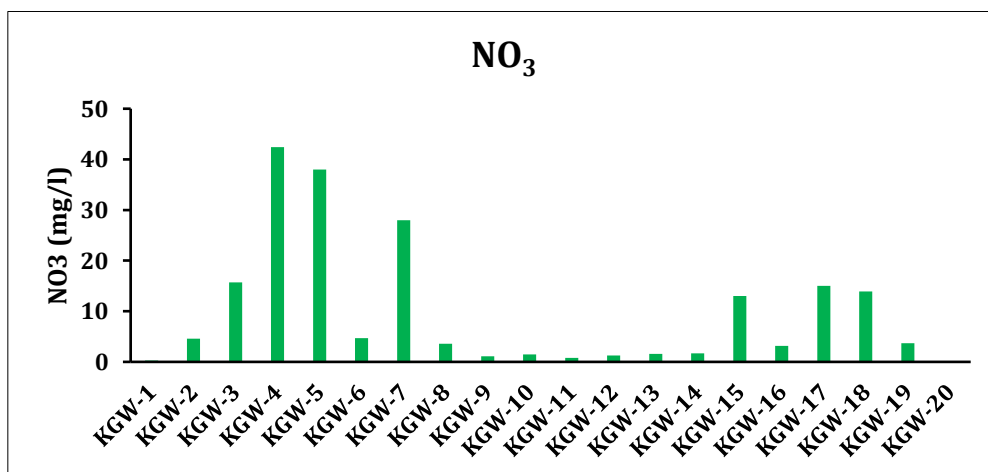


Figure 36: Nitrate (NO_3^-) concentration (mg/L) across the study sampling locations.

Nitrite concentrations in groundwater range from 0.0006 mg/L to 0.0849 mg/L, with most samples showing values below 0.01 mg/L. Elevated nitrite values are observed at KGW-6, KGW-9, KGW-4 and KGW-3, indicating transient nitrification–denitrification processes in shallow aquifers affected by recent organic input.

Nitrite anomalies are localized and shallow, with no association with NTPC facilities. BIS and WHO do not prescribe a specific nitrite limit for groundwater; observed values are well below toxic thresholds and represent short-term biogeochemical processes rather than persistent contamination.





Fluoride (F⁻)

Fluoride in groundwater is primarily controlled by geogenic factors, particularly the presence of fluoride-bearing minerals (e.g., fluorapatite, biotite, amphiboles) within basaltic formations, as well as alkaline pH, high bicarbonate concentration, long groundwater residence time, and low calcium activity, which together enhance fluoride solubility. In semi-arid regions such as Khargone, pre-monsoon conditions further accentuate fluoride enrichment due to evapoconcentration and reduced recharge.

In the present study, fluoride concentrations in groundwater samples collected during pre-monsoon (May 2025) range from low to moderately elevated, with higher concentrations recorded in piezometers located around the ash dyke of the NTPC Khargone power plant, namely KGW-9, KGW-10, KGW-11, KGW-12, KGW-13, and KGW-14. These piezometers are dedicated monitoring installations, designed to assess subsurface hydrogeochemical conditions and potential migration pathways, and are not used for drinking or domestic water supply.

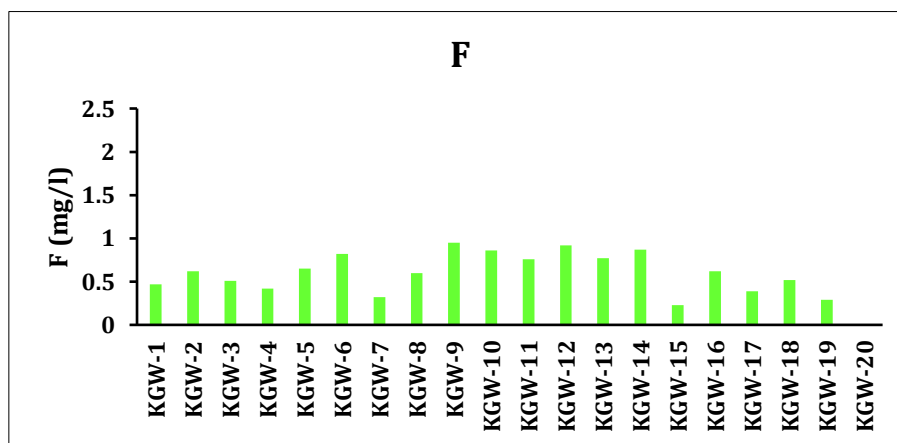


Figure 37: Fluoride (F⁻) concentration (mg/L) across the study sampling locations.

The elevated fluoride levels observed in these piezometer samples are interpreted as resulting from the natural geochemical evolution of deeper groundwater, characterized by longer residence time, higher alkalinity, bicarbonate dominance, and enhanced basalt–water interaction, rather than any anthropogenic or industrial influence. Importantly, there is no spatial correlation between fluoride concentration patterns and ash disposal activities, nor is there concurrent enrichment of other ash-





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associated indicators (such as sulphate, chloride, heavy metals, or EC) that would suggest ash-dyke interaction impact.

In contrast, groundwater samples collected from village wells and drinking-water sources generally show fluoride concentrations within the BIS and WHO desirable limit of 1.0 mg/L, with only a few locations approaching or marginally exceeding the permissible limit of 1.5 mg/L. These occurrences are consistent with regional groundwater conditions in basaltic terrains and are widely reported in central India.

From a regulatory and public health perspective, it is important to emphasize that:

- Fluoride exceedances observed in piezometer samples do not pose a direct health risk, as these sources are not connected to potable water supply.
- All drinking-water sources assessed in the study area remain largely compliant with BIS (IS 10500:2012) and WHO guidelines, except for localized, geogenic fluoride enrichment typical of the region.
- The fluoride data from piezometers serve as a baseline and early-warning indicator, confirming hydrogeochemical stability and absence of industrial contamination rather than compliance for human consumption.

Overall, the fluoride distribution pattern in groundwater of the NTPC Khargone area is controlled by natural geological and hydrogeochemical processes, with no evidence of contribution from NTPC plant operations or ash dyke seepage. Continued monitoring of piezometers is, however, recommended to track long-term trends in deeper aquifer chemistry and to ensure sustained protection of potable groundwater sources.

Phosphate (PO_4^{3-})

Phosphate concentrations in groundwater are generally very low, ranging from 0.0001 mg/L to 0.036 mg/L, with an average value of <0.005 mg/L. This reflects strong adsorption onto iron oxides, clay minerals, and basaltic weathering products.

However, localized phosphate enrichment is observed at KGW-5 and KGW-14, both located in village environments with shallow water tables, indicating influence from domestic wastewater, detergents, and agricultural runoff. There is no evidence of phosphate input from NTPC operations.



Although no BIS/WHO drinking-water guideline exists for phosphate, elevated concentrations may contribute to nutrient loading in hydraulically connected surface waters, highlighting a secondary environmental concern rather than a direct health issue.

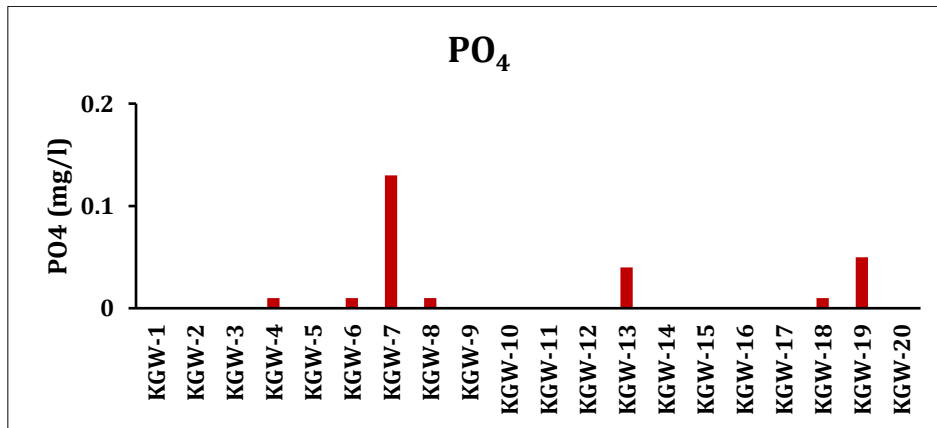


Figure 38: Phosphate (PO₄³⁻) concentration (mg/L) across the study sampling locations.

6.4.5 Normalized Ionic Charge Balance (NICB)

NICB values for groundwater samples range from -6.7% to +7.7%, indicating good analytical accuracy. All samples fall within the acceptable ±10% range, confirming the reliability of chemical analyses. Slight deviations in a few samples correspond to high bicarbonate and fluoride concentrations, reflecting complex geochemical interactions rather than analytical error.

6.4.6 Water Type and Hydro-chemical Facies

The Piper trilinear diagram is a widely used hydrogeochemical tool for identifying water types, ionic dominance, and evolutionary trends in groundwater and surface water systems. The diagram presents the relative distribution of major cations (Ca²⁺, Mg²⁺, Na⁺+K⁺) and major anions (HCO₃⁻+CO₃²⁻, Cl⁻, SO₄²⁻) for groundwater samples collected from piezometers around the ash dyke (piezometric groundwater) and village wells representing ambient groundwater. Numbered fields in the central diamond indicate dominant hydrochemical facies, while lettered fields in the triangular plots denote dominant cationic and anionic controls.

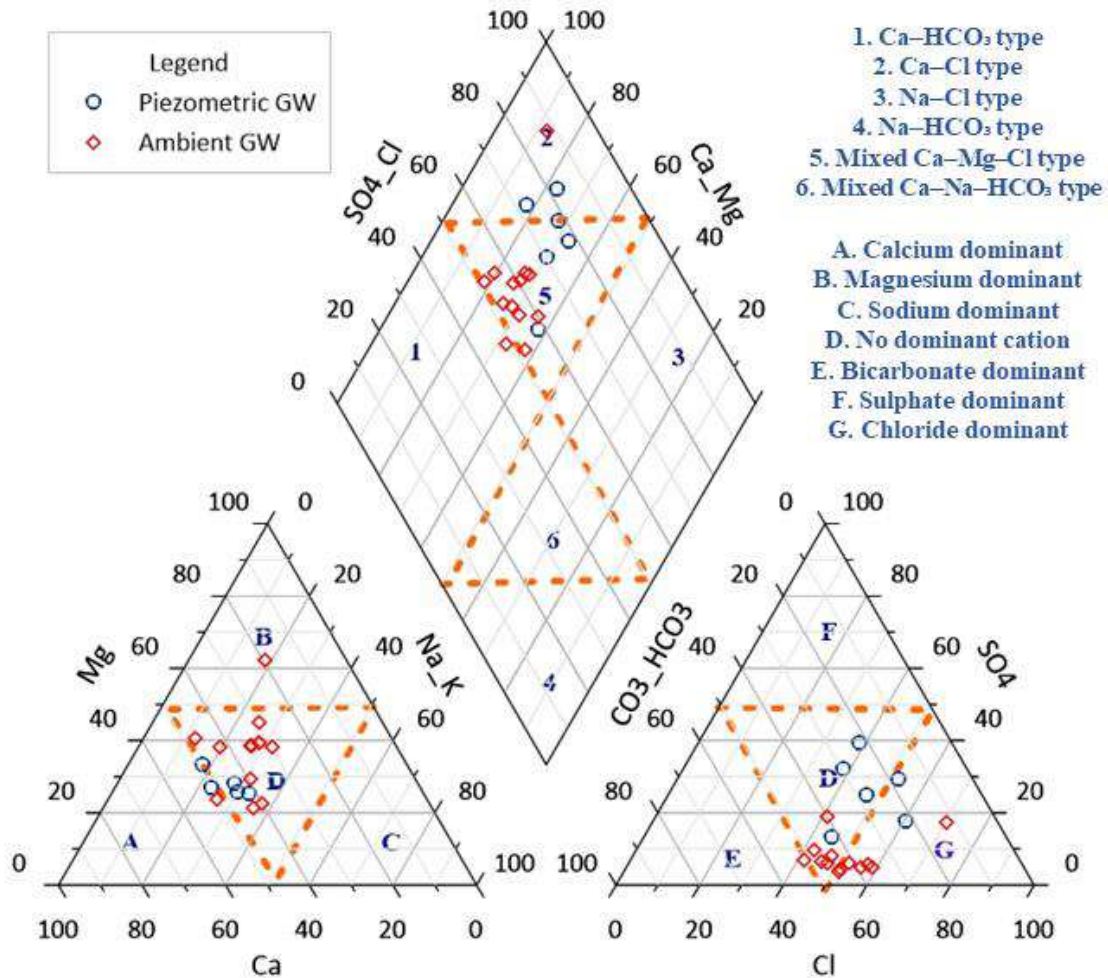


Figure 39: Piper Trilinear Diagram Showing Hydrogeochemical Facies of Groundwater in the NTPC Khargone Study Area (Pre-monsoon 2025).

The diagram presents the relative distribution of major cations (Ca^{2+} , Mg^{2+} , $\text{Na}^{+}\text{K}^{+}$) and major anions ($\text{HCO}_3^{-}+\text{CO}_3^{2-}$, Cl^{-} , SO_4^{2-}) for groundwater samples collected from piezometers around the ash dyke (piezometric groundwater) and village wells representing ambient groundwater. Numbered fields in the central diamond indicate dominant hydrochemical facies, while lettered fields in the triangular plots denote dominant cationic and anionic controls.

The Piper trilinear diagram was used to evaluate the major ion chemistry, hydrochemical facies, and evolutionary trends of groundwater in the NTPC Khargone area during the pre-monsoon season (2025). The distribution of groundwater



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samples in the cationic, anionic, and central diamond fields reveals a systematic hydrogeochemical pattern controlled primarily by lithology, groundwater depth, and residence time, with clear differentiation between piezometric groundwater and ambient groundwater.

In the cation triangle, the majority of groundwater samples plot within the calcium-dominant (Field A) and mixed Ca–Mg fields, indicating that alkaline earth metals ($\text{Ca}^{2+} + \text{Mg}^{2+}$) exceed alkali metals ($\text{Na}^+ + \text{K}^+$) in most locations. Ambient groundwater samples from village wells cluster predominantly toward the calcium-rich sector, reflecting active recharge, shorter residence time, and dominance of basaltic and carbonate weathering processes.

In contrast, piezometric groundwater samples show a slight shift toward sodium-enriched compositions, suggesting progressive ion exchange and longer water–rock interaction at greater depths around the ash dyke monitoring zone. However, none of the samples exhibit sodium dominance, indicating that the groundwater system has not evolved toward saline or sodic conditions.

The anion triangle demonstrates a strong dominance of bicarbonate (Field E) in both ambient and piezometric groundwater samples, confirming that weak acid anions (HCO_3^-) prevail over strong acid anions (SO_4^{2-} and Cl^-). Ambient groundwater samples cluster tightly within the bicarbonate field, characteristic of fresh recharge conditions and dissolution of CO_2 -rich soil gases and carbonate minerals.

Piezometric groundwater samples show relatively higher contributions of sulphate and chloride, with some plotting toward sulphate-dominant (Field F) or mixed bicarbonate–chloride fields. This trend reflects greater mineralization and longer residence time, rather than anthropogenic contamination, as sulphate and chloride concentrations remain within regulatory limits.

The central diamond field integrates cationic and anionic chemistry and reveals that groundwater in the study area is dominated by Ca–Mg– HCO_3 facies (Facies 1 and 6). This facies represents fresh, recently recharged groundwater controlled by rock–water interaction, and is most prominent in ambient groundwater used for drinking purposes.





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A subset of samples transitions toward Na-HCO₃ (Facies 4) and mixed Ca-Mg-Cl/SO₄ facies (Facies 5), primarily associated with piezometric groundwater. These transitional facies indicate hydrochemical evolution through cation exchange, mineral dissolution, and increased residence time, particularly in deeper aquifer zones surrounding the ash dyke. Importantly, no samples fall within the Na-Cl facies, confirming the absence of saline or industrially contaminated groundwater.

The Piper diagram clearly indicates that:

- Groundwater chemistry is geogenically controlled, dominated by basaltic weathering and bicarbonate alkalinity.
- Ambient groundwater exhibits fresh, Ca-Mg-HCO₃ type water suitable for drinking and domestic use.
- Piezometric groundwater reflects more evolved chemistry but remains within mixed facies without salinity dominance.
- There is no hydrochemical evidence of ash dyke seepage or industrial influence on potable aquifers.

Overall, the Piper diagram indicates a hydrochemically stable, naturally evolving groundwater system, with facies distribution governed by depth and residence time rather than by anthropogenic contamination.

6.4.7 Irrigation Suitability Assessment

The irrigation suitability of groundwater in the NTPC Khargone area was evaluated using the combined SAR-EC approach Figure 40 which assesses both salinity hazard (total dissolved salts) and sodicity hazard (sodium-induced soil dispersion).

Groundwater SAR values range from low to moderate, with all samples falling within the S1 (low sodium hazard) class. Ambient groundwater samples generally show SAR < 2, while piezometric groundwater samples display slightly higher SAR values at certain locations, reflecting longer residence time and progressive water-rock interaction. However, none of the samples approach the S2-S4 classes, indicating no risk of sodium-induced soil permeability reduction.

Groundwater EC values span C2 (medium salinity) to C3 (high salinity) classes. Ambient groundwater largely occupies the C2-C3 field, while piezometric

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groundwater, especially around the ash dyke, extends into the higher EC range, reflecting natural mineralization with depth rather than anthropogenic input.

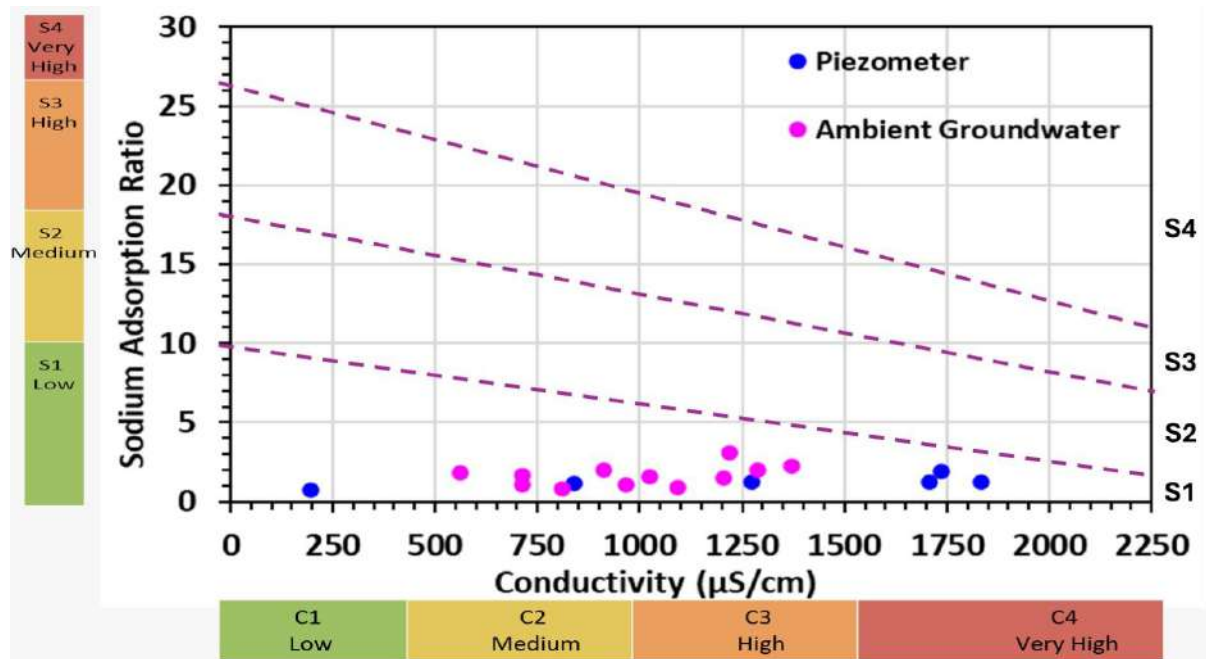


Figure 40: AR-EC Classification Diagram for Groundwater

This figure presents the relationship between Sodium Adsorption Ratio (SAR) and Electrical Conductivity (EC) for groundwater samples, classified into piezometric groundwater (monitoring wells around ash dyke) and ambient groundwater (village use zone). The diagram follows the US Salinity Laboratory (USSL) classification, indicating salinity hazard classes (C1-C4) and sodium hazard classes (S1-S4).

The combined SAR-EC classification places most groundwater samples in the C2-S1 and C3-S1 fields, indicating:

- Groundwater is generally suitable for irrigation,
- Use is appropriate for moderately salt-tolerant crops,
- Normal soil management and drainage practices are sufficient,
- No sodicity hazard exists even in higher-EC piezometric groundwater.

Thus, groundwater in the study area is safe for irrigation, with salinity being the only factor requiring minor management in localized high-EC zones.



6.4.8 Synthesis of Physico-Chemical Characteristics of Groundwater

The physico-chemical characteristics of groundwater in the NTPC Khargone study area, assessed during the pre-monsoon season (May 2025), indicate a system that is chemically stable, geogenically controlled, and largely unaffected by industrial activities. The observed groundwater quality reflects the combined influence of basaltic lithology of the Deccan Trap, depth-dependent residence time, seasonal concentration effects, and localized anthropogenic inputs in shallow aquifers.

Groundwater across the study area is mildly alkaline, with pH values generally ranging from neutral to moderately alkaline, consistent with bicarbonate buffering arising from silicate weathering and soil CO₂ interaction. Electrical conductivity and total dissolved solids exhibit moderate spatial variability, with higher values observed in deeper bore wells and piezometers located around the ash dyke and downgradient zones. These elevated values are attributed to longer groundwater residence time and pre-monsoon concentration, rather than salinity intrusion or industrial contamination. Importantly, all TDS values remain within the permissible limits prescribed by BIS (IS 10500:2012), confirming suitability for drinking and domestic use.

The major ion chemistry is dominated by Ca²⁺-HCO₃⁻ and Ca-Na-HCO₃ facies, as supported by Piper trilinear analysis, indicating groundwater evolution primarily governed by basalt weathering, carbonate dissolution, and cation-exchange processes. Calcium and bicarbonate together account for the majority of ionic composition, contributing to moderate to high hardness, which is geogenic in origin and poses no health risk. Sodium enrichment observed in deeper aquifers reflects advanced water-rock interaction and ion exchange, while remaining well within regulatory thresholds.

The distribution of major anions (HCO₃⁻, SO₄²⁻, Cl⁻, NO₃⁻, F⁻) further reinforces the dominance of natural hydrogeochemical processes, with bicarbonate as the principal anion. Sulphate and chloride occur at moderate concentrations and show no systematic enrichment near the ash dyke, indicating effective containment of ash disposal facilities. Nitrate and nitrite anomalies are confined to shallow village wells,



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highlighting localized influence of agricultural practices and domestic wastewater, with all values remaining below BIS/WHO limits.

Minor ions and nutrients such as phosphate and nitrite occur at very low concentrations in most groundwater samples due to strong adsorption and redox control, except at a few village locations where shallow groundwater is vulnerable to surface inputs. Dissolved silica concentrations, typical of basaltic aquifers, increase with groundwater depth and residence time, further confirming the geogenic control of groundwater chemistry.

Fluoride distribution exhibits a clear depth-dependent pattern, with elevated concentrations recorded primarily in piezometers around the ash dyke (KGW-9 to KGW-14). These piezometers are monitoring installations and not used for drinking purposes, and the fluoride enrichment is interpreted as natural, geogenic mobilization under alkaline, bicarbonate-rich conditions. Drinking-water sources generally remain within permissible limits, and no evidence of industrial contribution to fluoride is observed.

Overall, the synthesis of physico-chemical characteristics demonstrates that groundwater quality in the NTPC Khargone area is predominantly controlled by regional geology, hydrogeological setting, and seasonal factors, with localized anthropogenic influence restricted to shallow village aquifers. There is no evidence of deterioration of groundwater quality due to NTPC plant operations or ash dyke activities. The groundwater system remains largely compliant with BIS, WHO, and CPCB regulatory standards, and continued monitoring through the established network of wells and piezometers provides a robust framework for early detection and long-term protection of groundwater resources.





6.5 Trace Metals in Groundwater

Trace metals in groundwater are of particular concern due to their toxicity, persistence, and tendency to accumulate in biological systems. Unlike organic contaminants, trace metals are non-degradable and may remain in the subsurface environment for extended periods once mobilized. Their occurrence in groundwater is governed by a complex interaction of geological, hydrochemical, and anthropogenic factors, including mineralogy of the aquifer, redox conditions, pH, bicarbonate alkalinity, groundwater residence time, and land-use practices.

In the NTPC Khargone study area, trace-metal assessment was undertaken during the pre-monsoon season (May 2025) to evaluate both baseline geogenic conditions and the potential influence of industrial activities, particularly ash-dyke operations. To enable meaningful interpretation, groundwater samples were classified into two functional zones:

Zone I – Piezometers around the Ash Dyke

This group (KGW-9 to KGW-14) consists of dedicated monitoring piezometers installed around the ash dyke and plant premises. These sources:

- Tap deeper groundwater horizons,
- Are not used for drinking or domestic purposes, and
- Are intended to serve as early-warning and compliance monitoring points for subsurface migration.

Trace-metal concentrations in this zone are interpreted in terms of hydrogeochemical evolution and monitoring significance, not human exposure.

Zone II – Groundwater from Localities around the Plant

This group (KGW-1 to KGW-19) represents hand pumps and bore wells used for drinking and domestic supply in nearby villages. These samples are:

- Mostly from shallow to intermediate aquifers,
- More vulnerable to surface-derived inputs, and
- Directly relevant for public health and regulatory compliance.



This zonal distinction is critical to avoid misinterpretation of monitoring data and to ensure that regulatory compliance is assessed only for potable water sources, in line with BIS and WHO norms.

Table 12: Trace metal concentration ppb in the Ground water of the study area during pre-monsoon 2025.

S.No.	Sample ID	As	Cd	Cr	Hg	Pb	Zn	Ni	Cu	Fe	Ba
1	KGW-1	0.6	0.04	1.7	1.0	8.3	18.6	1.0	20.2	1384.3	8.6
2	KGW-2	1.3	0.04	1.3	0.8	3.7	3.9	1.0	1.1	167.4	5.0
3	KGW-3	0.8	0.07	1.5	0.4	11.6	157.9	1.6	33.0	716.6	3.2
4	KGW-4	0.8	BDL	1.5	0.4	4.3	112.6	1.0	18.0	1327.3	5.0
5	KGW-5	0.5	BDL	3.7	0.6	2.3	17.6	6.1	27.5	3716.6	39.4
6	KGW-6	0.5	0.04	0.8	0.5	6.1	233.2	0.4	4.5	297.2	2.2
7	KGW-7	0.5	0.11	1.4	0.2	5.5	84.2	1.3	15.4	441.5	6.1
8	KGW-8	0.3	BDL	1.2	0.4	5.8	66.3	2.1	2.7	219.2	4.5
9	KGW-9	0.4	0.04	4.1	0.5	63.4	239.5	10.4	29.8	2426.9	34.1
10	KGW-10	0.5	BDL	3.6	0.1	9.1	23.1	6.8	12.3	987.0	21.5
11	KGW-11	0.3	0.04	3.1	0.4	33.9	13.9	8.5	32.8	4119.2	19.9
12	KGW-12	0.4	0.15	2.2	0.3	102.1	18.0	2.7	11.8	1927.3	14.1
13	KGW-13	0.9	BDL	4.9	0.5	11.4	102.6	5.4	8.3	1482.5	19.7
14	KGW-14	0.5	BDL	1.6	0.6	72.6	113.5	1.8	6.5	722.7	8.9
15	KGW-15	1.8	0.04	1.2	0.0	2.2	9.2	0.6	2.0	51.9	24.5
16	KGW-16	0.3	0.04	1.5	BDL	4.4	26.1	0.5	7.9	349.4	5.7
17	KGW-17	0.5	0.04	1.1	0.1	3.2	9.3	0.1	4.6	54.8	6.3
18	KGW-18	0.6	BDL	0.9	0.2	1.8	28.0	6.7	2.1	447.8	28.8
19	KGW-19	1.1	0.07	2.1	0.6	7.2	387.3	2.0	6.0	369.1	74.7

6.5.1 Iron (Fe)

Iron is the most abundant trace metal in groundwater of the Khargone region and shows wide spatial variability. Concentrations range from ~52 µg/L to ~4119 µg/L, with the highest values consistently observed in piezometers (KGW-9, KGW-11, KGW-12) and a few village wells (KGW-5).

Elevated iron concentrations are characteristic of basaltic aquifers under reducing or sub-oxic conditions, where dissolution of iron-bearing minerals and reductive dissolution of iron oxides occurs. High iron is strongly associated with groundwater depth and residence time, and often coincides with high bicarbonate and low dissolved oxygen.

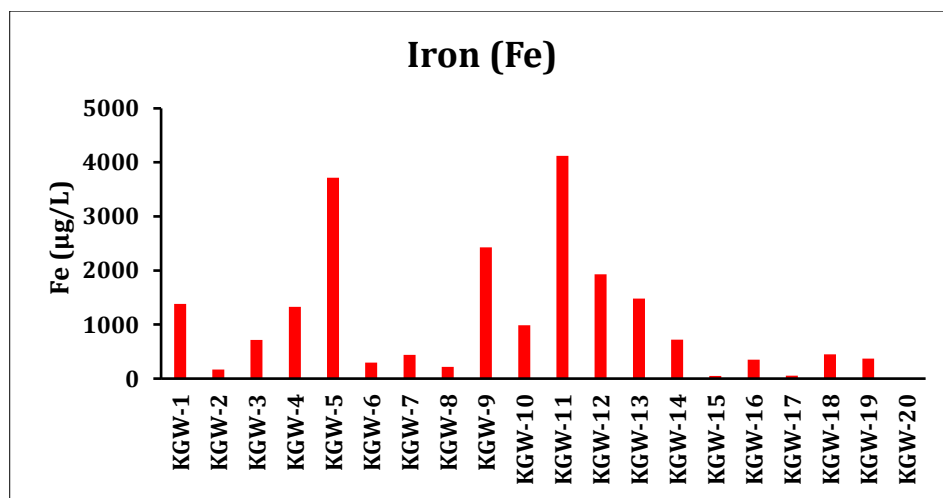


Figure 41: Iron (Fe) concentration (µg/L) across the study sampling locations.

Although iron frequently exceeds the BIS aesthetic guideline (300 µg/L), it does not pose a health risk and is not subject to CPCB effluent limits for groundwater. Importantly, high iron values in piezometers do not indicate ash-dyke contamination, as no concurrent enrichment of sulphate, chloride, EC or toxic metals is observed.

6.5.2 Arsenic (As)

Arsenic concentrations across all groundwater samples range from 0.3 to 1.8 µg/L, which is well below the BIS and WHO guideline value of 10 µg/L. Slightly higher values occur in deeper piezometer samples (KGW-13, KGW-15), reflecting natural release from mineral phases under alkaline, bicarbonate-rich conditions.

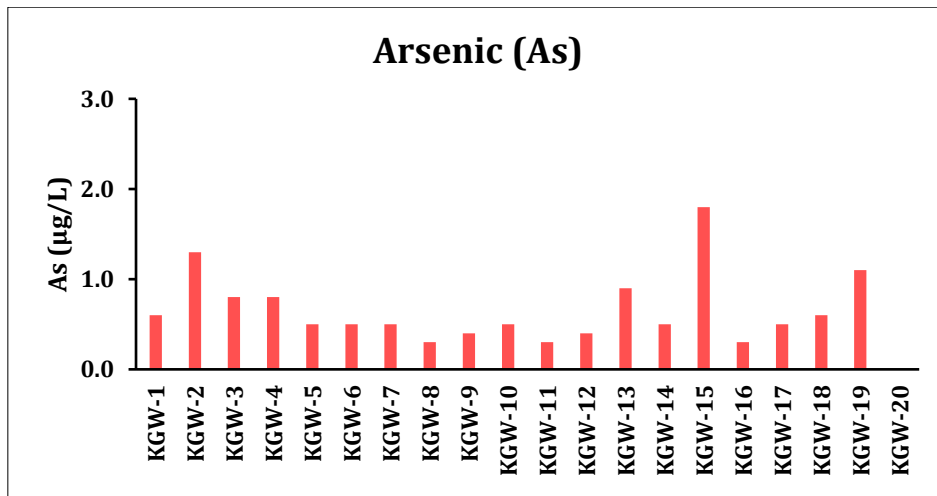


Figure 42: Arsenic (As) concentration (µg/L) across the study sampling locations.

There is no spatial clustering of arsenic near the ash dyke, and concentrations in drinking-water sources are uniformly low, confirming absence of arsenic-related health risk in the study area.

6.5.3 Cadmium (Cd)

Cadmium is a highly toxic, non-essential metal; however, in the present study it occurs only at trace to near-detection levels (ND to 0.15 µg/L). All values are far below the BIS permissible limit of 3 µg/L.

Detected cadmium does not show any spatial pattern or association with industrial zones, indicating background-level occurrence rather than anthropogenic contamination.

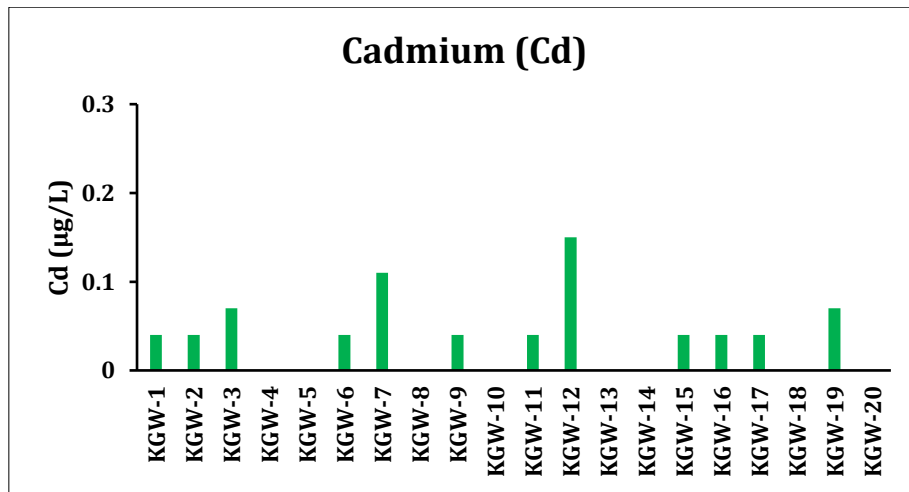


Figure 43: Cadmium (Cd) concentration (µg/L) across the study sampling locations.

6.5.4 Chromium (Cr)

Total chromium concentrations range from ~0.8 to 4.9 µg/L, remaining well within the BIS limit of 50 µg/L. Slightly higher chromium values in a few piezometer samples reflect natural weathering of mafic minerals in basalt.

No evidence of chromium contamination related to industrial effluents or ash disposal is observed.

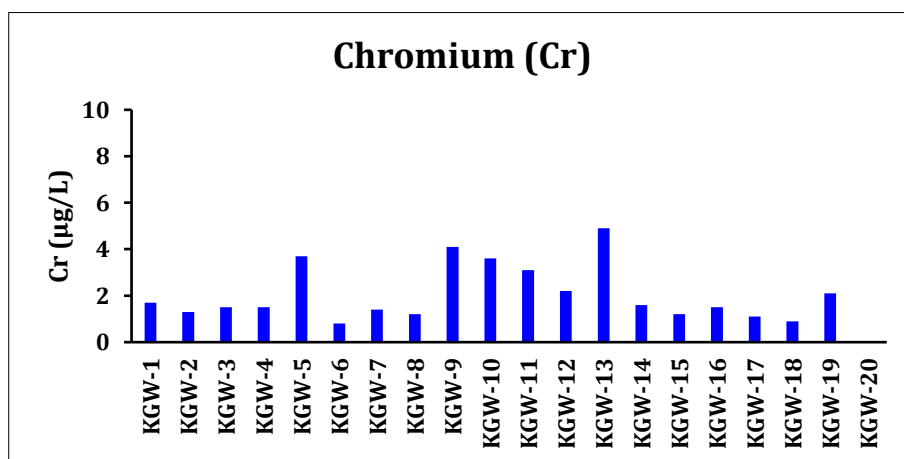


Figure 44: Chromium (Cr) concentration (µg/L) across the study sampling locations.



6.5.5 Mercury (Hg)

Mercury is detected at very low concentrations (ND to ~1.0 µg/L). All drinking-water sources comply with the BIS guideline value of 1 µg/L, and slightly higher values in piezometers are still well below CPCB effluent thresholds.

Mercury distribution shows no spatial linkage to NTPC facilities, suggesting absence of industrial mercury input.

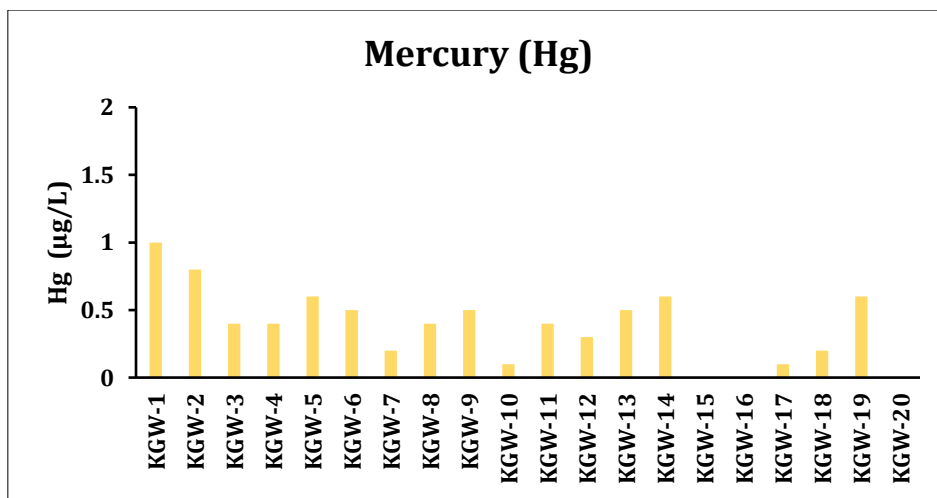


Figure 45: Mercury (Hg) concentration (µg/L) across the study sampling locations.

6.5.6 Lead (Pb)

Lead concentrations show a clear zonal contrast. Elevated values (up to ~102 µg/L) are recorded in piezometers around the ash dyke, while village drinking-water sources mostly remain below the BIS limit of 10 µg/L.

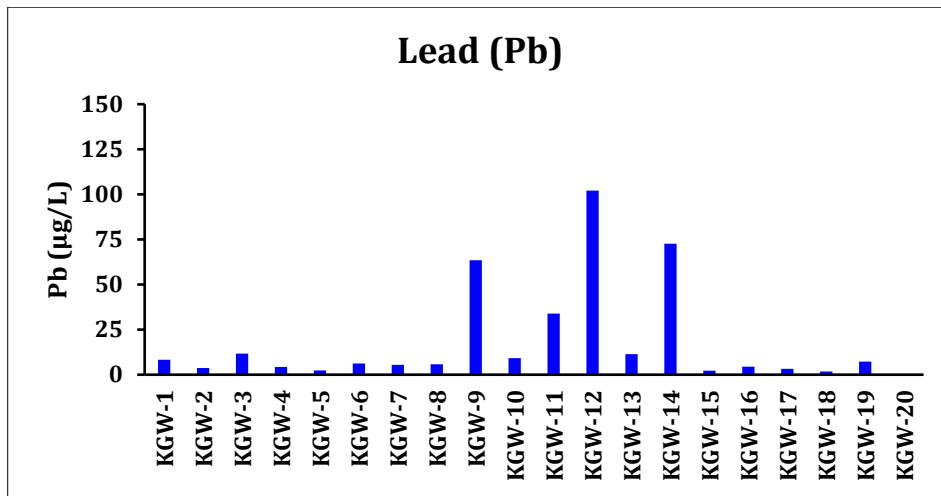


Figure 46: Lead (Pb) concentration (µg/L) across the study sampling locations.

The higher lead values in piezometers are interpreted as geogenic mobilization under deeper aquifer conditions, potentially influenced by redox chemistry and mineral dissolution. Since these piezometers are not used for drinking, they do not represent a public health risk. Importantly, no progressive increase toward village wells is observed.

6.5.7 Zinc (Zn)

Zinc concentrations vary from ~3.9 to ~387 µg/L, with higher values at KGW-6 and KGW-19, yet remain far below the BIS permissible limit of 5000 µg/L. Zinc is an essential element, and observed concentrations are well within safe limits. Zinc enrichment is likely related to natural mineral weathering and minor agricultural inputs, rather than industrial sources.

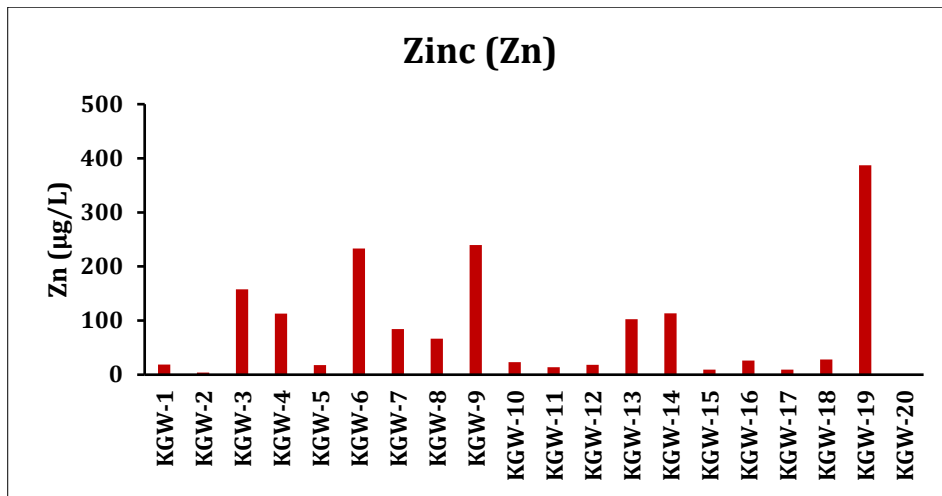


Figure 47: Zinc (Zn) concentration (µg/L) across the study sampling locations.

6.5.8 Nickel (Ni)

Nickel occurs at trace levels (0.1–10.4 µg/L) across the study area, well below the BIS guideline value of 20 µg/L. Slightly higher nickel values in piezometers reflect mafic mineral dissolution typical of basaltic lithology.

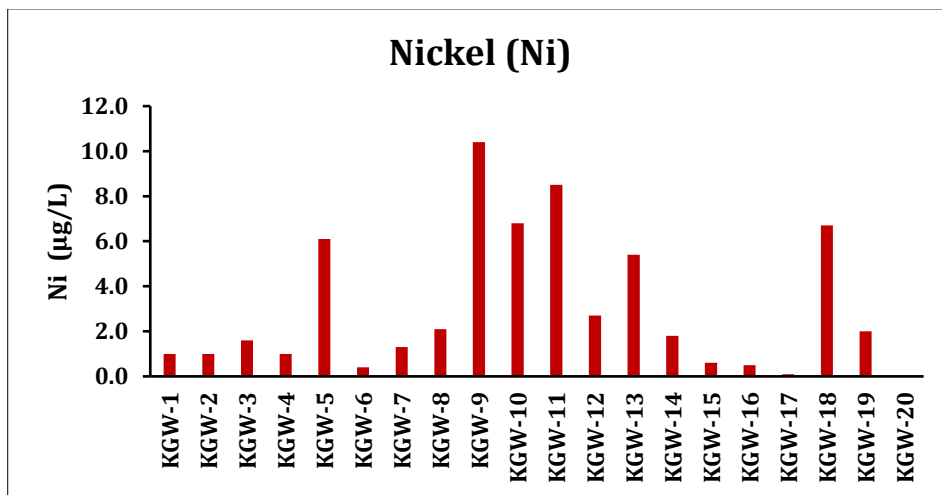


Figure 48: Nickel (Ni) concentration (µg/L) across the study sampling locations.

6.5.9 Copper (Cu)

Copper concentrations range from ~1.1 to ~33 µg/L, remaining well within the BIS limit of 50 µg/L. Copper distribution shows no systematic spatial trend and does not indicate anthropogenic enrichment.

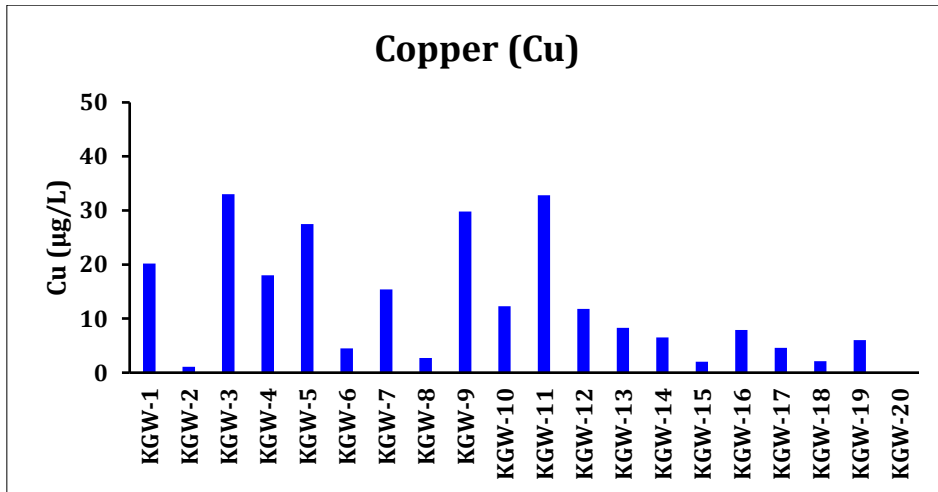


Figure 49: Copper (Cu) concentration (µg/L) across the study sampling locations.

6.5.10 Barium (Ba)

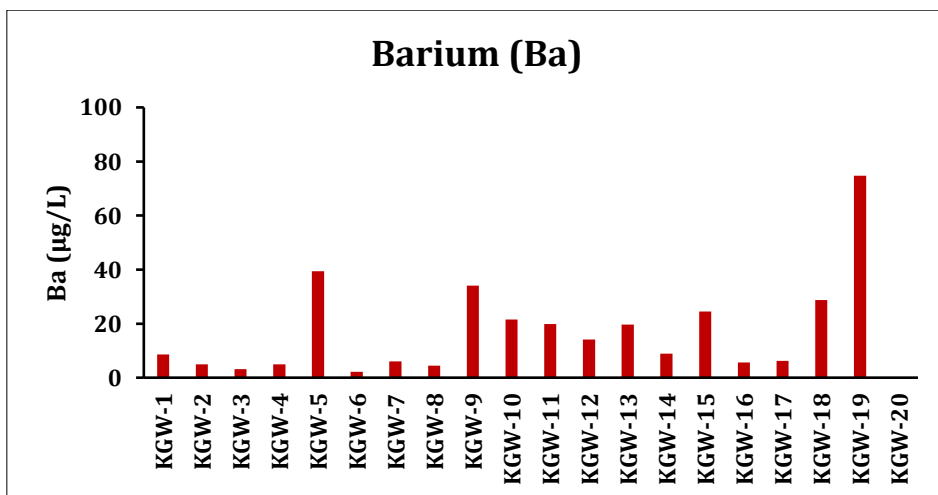


Figure 50: Barium (Ba) concentration (µg/L) across the study sampling locations.

Barium concentrations vary from ~2 to 75 µg/L, far below the BIS guideline value of 700 µg/L. Barium occurrence is entirely geogenic, derived from the dissolution of feldspar and accessory minerals.



6.6 Synthesis of Trace Metals in Groundwater: Compliance, Risk and Hydrogeochemical Interpretation

The integrated assessment of trace metals in groundwater in the NTPC Khargone study area, based on pre-monsoon (May 2025) monitoring, indicates that observed metal concentrations are predominantly controlled by natural hydrogeochemical processes, with no evidence of adverse effects from thermal power plant operations or ash-dyke facilities.

A clear zonal distinction emerges in the trace-metal distribution. Piezometers installed around the ash dyke consistently record relatively higher concentrations of certain metals such as iron, lead, zinc, and nickel. These elevations are attributed to greater groundwater depth, longer residence time, alkaline pH, bicarbonate dominance, and localized reducing conditions, which collectively enhance mineral dissolution and metal mobility in basaltic aquifers. Importantly, these piezometers function solely as monitoring and early-warning installations and are not used for drinking or domestic supply; therefore, they do not represent a direct pathway for human exposure.

In contrast, groundwater sources from surrounding villages and localities, which are used for drinking and domestic purposes, exhibit consistently lower metal concentrations. All such potable sources remain well within the permissible limits prescribed by BIS (IS 10500:2012) and WHO guidelines for toxic metals, including arsenic, cadmium, chromium, mercury, lead, nickel, copper, zinc, and barium. Minor exceedances of aesthetic parameters, such as iron, are locally observed but do not constitute a health concern and are typical of basalt-dominated aquifers in central India.

From a regulatory compliance perspective, the groundwater quality fully satisfies applicable drinking-water standards. Even the elevated metal concentrations observed in piezometers remain far below CPCB effluent thresholds, reinforcing the conclusion that ash-dyke seepage or industrial leachate migration is not occurring. The absence of co-enrichment of diagnostic indicators such as sulphate, chloride, EC, or toxic metals further corroborates this interpretation.



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In terms of risk characterization, the current groundwater system presents low environmental and negligible public health risks. Trace metals exhibit stable spatial patterns, lack progressive down-gradient increase toward habitation zones, and show no synergistic contamination signature. Seasonal concentration during pre-monsoon conditions reflects natural concentration effects due to reduced recharge, rather than anthropogenic loading.

Overall, the synthesis of trace-metal data demonstrates that groundwater in the NTPC Khargone area is chemically stable, geogenically governed, and compliant with national and international standards. The existing monitoring network—particularly the piezometers around the ash dyke—provides a robust and precautionary framework for long-term surveillance. Continued periodic monitoring is recommended as a best environmental practice to ensure sustained groundwater protection and regulatory assurance.

6.7 Integrated Synthesis of Major Ions and Trace Metals in Groundwater

The combined evaluation of physicochemical parameters, major ions, hydrochemical facies, and trace metals in groundwater in the NTPC Khargone study area indicates a coherent, geogenically controlled hydrogeochemical system, with no evidence of contamination attributable to thermal power plant operations or ash-dyke facilities. Groundwater chemistry reflects the interaction among basaltic lithology, aquifer depth, groundwater residence time, seasonal hydrologic conditions, and localized land-use practices, particularly during the pre-monsoon period (May 2025).

6.8 Trace Metals in Relation to Major Ion Chemistry

The distribution of trace metals closely mirrors the major-ion hydrochemistry, reinforcing a natural geochemical control. Elevated concentrations of iron, lead, zinc, and nickel are preferentially observed in bicarbonate-rich, low-DO, deeper groundwater sampled from piezometers, where alkaline conditions and reducing environments enhance metal solubility. These conditions are characteristic of basalt aquifers with extended groundwater residence time and do not indicate industrial contamination.





In contrast, groundwater from drinking-water sources in surrounding villages consistently exhibits lower trace-metal concentrations, remaining well within BIS and WHO guideline values for all toxic metals, including arsenic, cadmium, chromium, mercury, lead, nickel, copper, zinc, and barium. The absence of concurrent enrichment of sulphate, chloride, EC, or toxic metals further confirms that ash-dyke seepage or power-plant related leachate migration is not influencing potable aquifers.

6.9 Coupled Behaviour of Ions and Metals

The integrated dataset demonstrates a strong coupling between major ions and trace metals, where:

- High bicarbonate and alkaline pH promote dissolution of iron, lead, and zinc from aquifer minerals,
- Low dissolved oxygen favors reductive mobilization of iron and associated trace metals, and
- Stable chloride and sulphate levels indicate minimal anthropogenic or industrial input.

This coupled behaviour supports the interpretation that the evolution of groundwater quality is internally regulated by water–rock interaction, rather than externally driven by pollution sources.

6.10 Compliance, Risk, and Environmental Significance

From a regulatory compliance standpoint, groundwater quality in the NTPC Khargone area is fully compliant with BIS (IS 10500:2012) and WHO drinking-water standards for all health-relevant parameters. Trace-metal concentrations observed in piezometers, although occasionally elevated, remain below CPCB effluent thresholds and occur in non-potable monitoring wells, posing no direct human health risk.

The integrated assessment indicates:

- Low environmental risk,
- Negligible public-health concern, and



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- High confidence in the effectiveness of existing ash-management and groundwater-protection measures.

Overall Interpretation

In summary, the combined major-ion and trace-metal chemistry of groundwater in the NTPC Khargone area reflects a hydrogeochemically mature, basalt-controlled aquifer system, characterized by bicarbonate dominance, limited salinization, and trace-metal levels governed by natural geochemical processes. The observed groundwater quality is stable, compliant, and protective of human and ecological receptors, with the existing monitoring framework providing a robust and precautionary basis for long-term groundwater stewardship.





7 ISOTOPIC CHARACTERISTIC

7.1 Introduction

Isotopes can be used to study the different facets of the hydrologic cycle. However, the use of different types of isotopes, i.e., radioactive (artificial) -sealed or tracers, radioactive (environmental) or stable isotopes, depends upon the type and requirement of the study to be carried out. The major applications of isotopes in groundwater hydrology that may be useful for arid and semiarid regions are listed below.

- Groundwater recharge
- Groundwater flow velocity and direction (Dilution techniques)
- Origin of groundwater
- Recharge zones and sources to deeper aquifers
- Effectiveness of artificial recharge measures
- Groundwater salinization

The information on aquifer dynamics can be used to understand the availability of groundwater/replenishment, the sustainability of springs, origin and source of groundwater, artificial measures to increase groundwater recharge, the discharge of springs, and the control of soil erosion from the high erosion-prone areas to manage the watersheds in an effective manner.

Studies conducted worldwide during last few decades have established that stable oxygen and hydrogen isotope ratios provide useful tools for hydrological investigations (Clark and Fritz, 1997; Mazor, 1991; Fontes, 1980). In India, stable isotopes have been used to estimate recharge rates and to identify the recharge zones, to determine the effect of evaporation on groundwater system, to estimate diffusion rates in unsaturated zones, to study the groundwater surface water interaction and to identify source of salinity in groundwater (Bhattacharya et al., 1985, Navada et al., 1986; Deshpande et al., 2003; Rai et al. 2006). Variations in stable isotopic compositions of oxygen and hydrogen constituting the water molecule (also referred to as stable water isotopes) have been used to identify water sources and groundwater recharge. This has been possible because stable water isotopes are influenced directly by the atmospheric processes (e.g. water vapour



advection, condensation, or evaporation) and during groundwater recharge (e.g., precipitation, evapotranspiration, mixing, and dispersion). Interpretation of isotope data is often complicated because multiple simultaneous processes can affect the evolution of isotope character in particular rain events and in surface/groundwater bodies. It is, therefore, necessary to monitor any changes in the isotopic composition of groundwater in time and space. In the present study, groundwater samples were systematically collected all over the district to characterize the isotopic signature of groundwater and to understand the source of water.

7.2 Basic of Isotope Technique

Isotopes are the atoms of an element having the same atomic number (Z) but different atomic weight (A). In other words, the atoms of an element having a different number of neutrons (N) but the same number of protons or electrons are called isotopes. For example, hydrogen has three isotopes having the same atomic number of 1 but different atomic masses 1, 2, and 3 or weights of 1, 2, and 3, respectively, i.e., 1H^0 , 1H^1 , and 2H^2 .

Similarly, oxygen has eleven isotopes, 12O , 13O , 14O , 15O , 16O , 17O , 18O , 19O , 20O , 21O and 22O , but except 16O , 17O , and 18O all other isotopes are radioactive and their existence in nature is very small (half-life vary from 150 seconds to few femo seconds - of the order 10-15 seconds) therefore, we normally talk about only three isotopes of oxygen i.e., 16O , 17O , and 18O .

7.2.1 Classification of Isotopes

Isotopes can be classified into two important categories: (i) stable isotopes and (ii) unstable isotopes. Stable isotopes are atoms of an element that are in a stable configuration of protons, neutrons, and electrons. On the other hand, unstable isotopes are atoms of an element that are not in a stable configuration of atomic particles and disintegrate by emitting alpha, beta, or gamma radiation, transforming into another type of atom. This process continues until a stable nuclide (element) is formed. Because of their disintegration or emission of radiation, unstable isotopes are also called radioactive isotopes. For example, 1H and 2H are stable isotopes, while 3H is unstable. Similarly, 12C and 13C are stable isotopes,



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while ^{14}C is unstable. On the other hand, isotopes of oxygen (^{16}O , ^{17}O , and ^{18}O) are stable.

Isotopes can also be classified as natural and artificial. Isotopes that occur naturally are called natural isotopes, while those produced in a reactor or laboratory under controlled conditions are known as artificial isotopes. Normally, artificially produced isotopes are radioactive, whereas stable and radioactive isotopes both occur naturally. Another category of isotopes, called environmental isotopes, has been devised. These include naturally occurring stable and radioactive isotopes, as well as radioisotopes introduced into the atmosphere due to anthropogenic activities, etc. Environmental radioisotopes, whether naturally occurring due to cosmic-ray interactions with various gaseous molecules or anthropogenically produced and incorporated into the hydrological cycle, are safe under normal conditions and do not pose any threat to human health. The following diagram illustrates the classification of isotopes.

Measurements of stable isotopes are done in terms of abundance ratios i.e. atomic mass of the heavy atom to the atomic mass of light atom. For example, heavy water $^2\text{H}^2^{16}\text{O}$, (D^2^{16}O) has a mass of 20 compared to normal water $^1\text{H}^2\text{O}$, which has a mass of 18. Similarly, a heavier stable molecule of water D_2^{18}O has a mass of 22. This is because of the variation in the number of neutrons. However, the absolute abundance ratio of isotopes is not usually measured in natural waters and other components. Only the relative difference in the ratio of the heavy isotopes to the more abundant light isotope of the sample with respect to a reference is determined. The difference is designated by a Greek letter δ and is defined as follows:

$$\delta = (R_{\text{sample}} - R_{\text{reference}}) / R_{\text{reference}}$$

Where R's are the ratios of the $^{18}\text{O}/^{16}\text{O}$ and D/H isotopes in the case of water.

The difference between samples and references is usually quite small, δ values are therefore expressed in per mille differences (‰) i.e., per thousand.

$$\delta (\text{‰}) = \delta \times 1000.$$

$$\delta (\text{‰}) = [(R_s - R_r) / R_r] \times 10^3 = [(R_s / R_r) - 1] \times 10^3$$





If the δ value is positive, it refers to the enrichment of the sample in the heavy-isotope species with respect to the reference, and a negative value corresponds to the sample depleted in the heavy-isotope species.

The reference standards normally considered are VSMOW (Vienna Standard Mean Ocean Water). Craig evaluated the isotopic ratios of SMOW as;

$$^{18}\text{O}/^{16}\text{O} = (1993.4 \pm 2.5) \times 10^{-6} \text{ and } \text{D}/\text{H} = (158 \pm 2) \times 10^{-6}$$

7.2.2 Collection of Groundwater Sample

To identify the isotopic signatures of groundwater, samples were collected from India mark hand pumps, ponds, the river, and the ash pond. When the groundwater samples were collected from hand-pumps and piezometers, the samples were collected after purging the standing water column for a few minutes. On-site measurements like sample temperature, pH, and conductivity, along with all other relevant site information, were also recorded. For stable isotope measurements, samples were collected in pre-cleaned 60 ml Polypropylene bottles (Tarsons make). These were rinsed thoroughly at the site with sample water, filled with water samples, tightly capped (to prevent evaporation and exchange with atmospheric moisture), and transported to the laboratory at NIH Roorkee for isotopic analysis.

The oxygen and hydrogen isotope measurements were carried out using a Dual Inlet Isotope Ratio Mass Spectrometer (GV instruments, UK) with automatic sample preparation units at the National Institute of Hydrology, Roorkee. Along with each batch of samples, secondary standards developed with reference to primary standards (i.e., V-SMOW, SLAP, GISP) were also measured, and the final δ -values were calculated using a triple point calibration equation. The overall precision, based on 10 points of repeated measurements of each sample, was $\pm 0.1\%$ for $\delta^{18}\text{O}$ and $\pm 1\%$ for δD .



Table 13: Pre-monsoon 2025 stable isotope composition ($\delta^{18}\text{O}$, δD , and d-excess) of surface water samples from different sources in the study area.

S.No.	Code	Source	dO18	dD	d-excess
Pre-monsoon					
1	KSW-1	Pond	6.06	17.12	-31.34
2	KSW-2	Pond	-3.83	-31.23	-0.62
3	KSW-3	Reservoir Pond	0.66	-3.90	-9.21
4	KSW-5	River	-1.11	-16.66	-7.81
5	KSW-6	Pond	6.36	22.76	-28.09
6	KSW-7	Pond	0.06	-15.32	-15.77
7	KSW-9	Ash Dyke	1.68	2.43	-11.01
8	KSW-10	Ash dyke	2.20	0.24	-17.35
9	KSW-11	NTPC Reservoir	-3.76	-30.73	-0.64
10	KSW-12	Pond	0.52	-10.86	-15.04
11	KSW-14	Narmada Upstream	-3.80	-32.92	-2.51
12	KSW-15	River	1.23	-8.33	-18.20

7.3 Results

7.3.1 Isotopic Composition of Water Samples

The d^{18}O - dD bi plot of precipitation in the study area is constructed from the Indian Meteoric Water Line for the central Indian region (Sagar) (Kumar et al. 2010).

$$\text{LMWL: } \text{dD} = 7.91 (\pm 0.29) \times \text{d}^{18}\text{O} + 8.23 (\pm 1.81); R^2 = 0.99$$

The Pre-monsoon and Post-monsoon oxygen isotope ratios ($\delta^{18}\text{O}$) of groundwater samples varied from 2.0‰ (max) to -5.9‰ (min) and -0.9‰ (max) to -3.4‰ (min), respectively. Whereas, Pre-monsoon and Post-monsoon hydrogen isotopic ratio (δD) varies from 8.9‰ (max) to -44.3‰ (min) and 22.8‰ (max) to -32.9‰ (min), respectively. Similarly, Pre-monsoon oxygen isotope ratio ($\delta^{18}\text{O}$) of surface water samples varied from 6.4‰ (max) to -3.8‰ (min). Whereas, the hydrogen isotopic ratio (δD) varies from 22.8‰ (max) to ‰ (min).

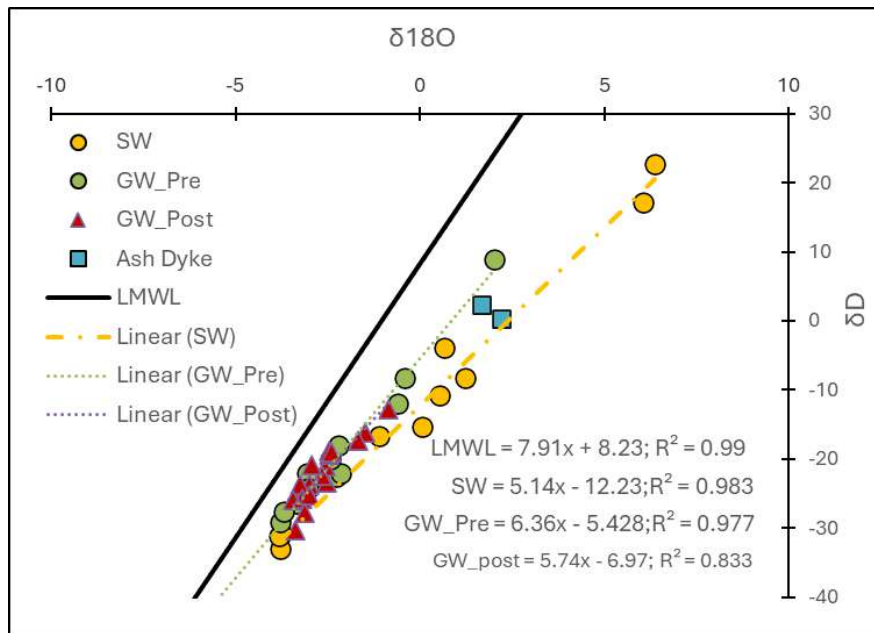


Figure 51: $\delta^{18}\text{O}$ vs δD (in per min (‰)) plot for groundwater (pre and post monsoon), surface water, and ash dyke in the study area.

Moreover, the oxygen isotope ratio ($\delta^{18}\text{O}$) of ash pond samples KSW-09 and KSW-10 are 1.7‰ and 2.2‰, and the hydrogen isotopic ratio (δD) is 2.4‰ and 0.24‰, respectively. Whereas, the pre-monsoon, Narmada River water sample isotopic composition of oxygen and hydrogen isotope ratio ($\delta^{18}\text{O}$ and δD) is -3.8‰ and -32.9‰, respectively. This indicates that there is a high amount of enrichment due to evaporation in the raw water and the ash dyke water.

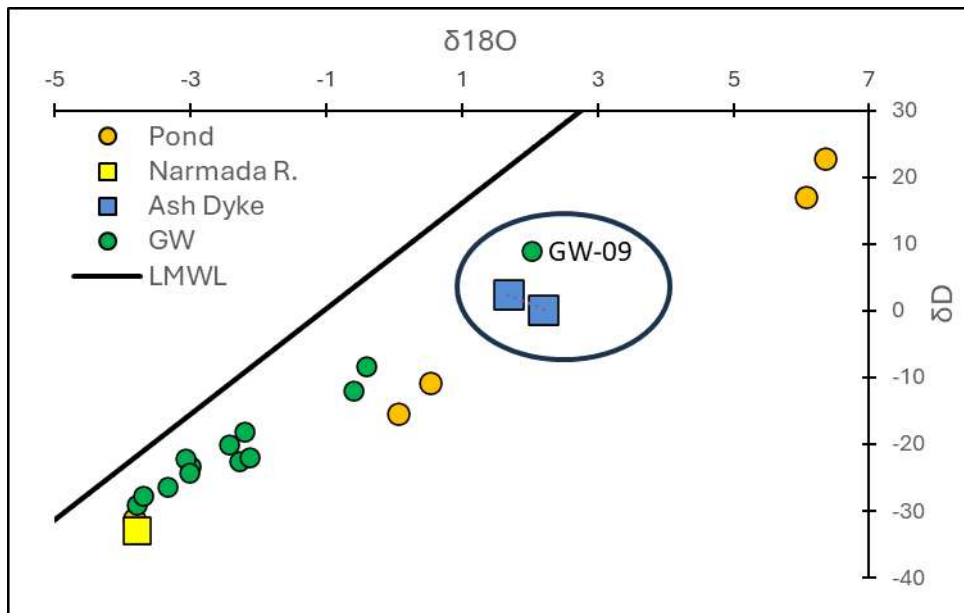


Figure 52: $\delta^{18}\text{O}$ vs δD (in per min (‰)) plot for groundwater (pre monsoon), Narmada River, Pond water and ash dyke in the study area

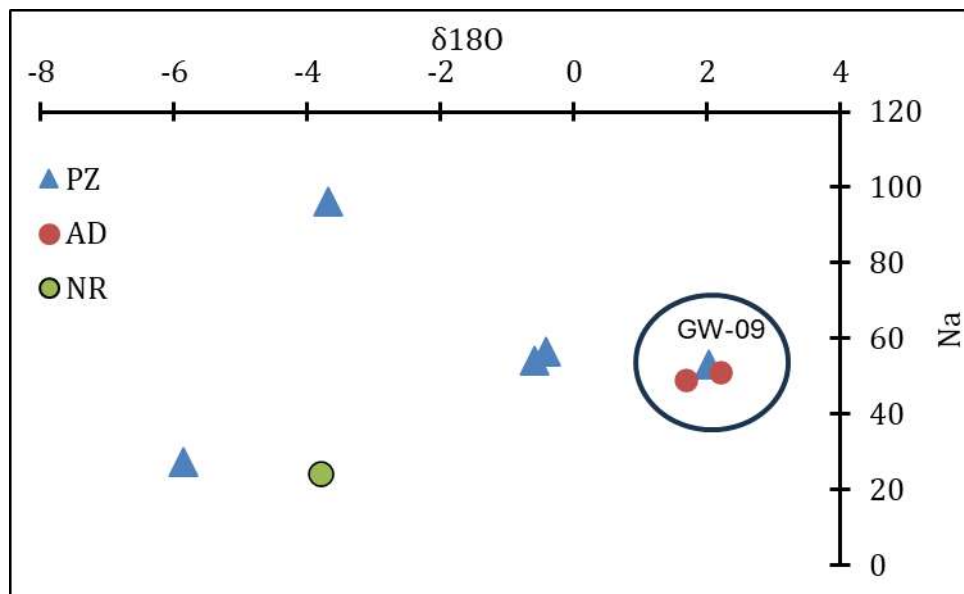


Figure 53: $\delta^{18}\text{O}$ vs Na (in per min (‰)) plot for Piezometer (PZ) (pre monsoon), Narmada River (NR), and Ash dyke (AD) in the study area

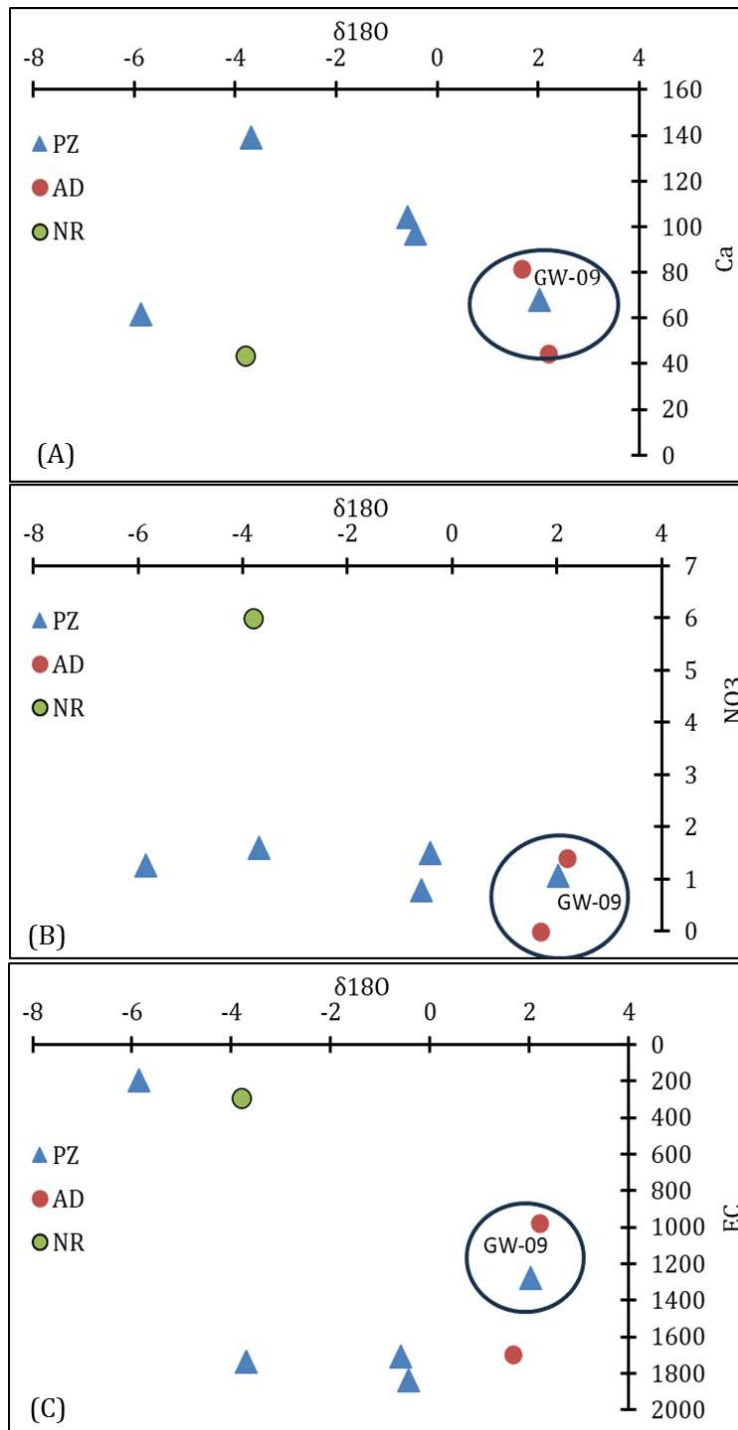


Figure 54: Piezometer (PZ) (pre monsoon), Narmada River (NR), and Ash dyke (AD) in the study area

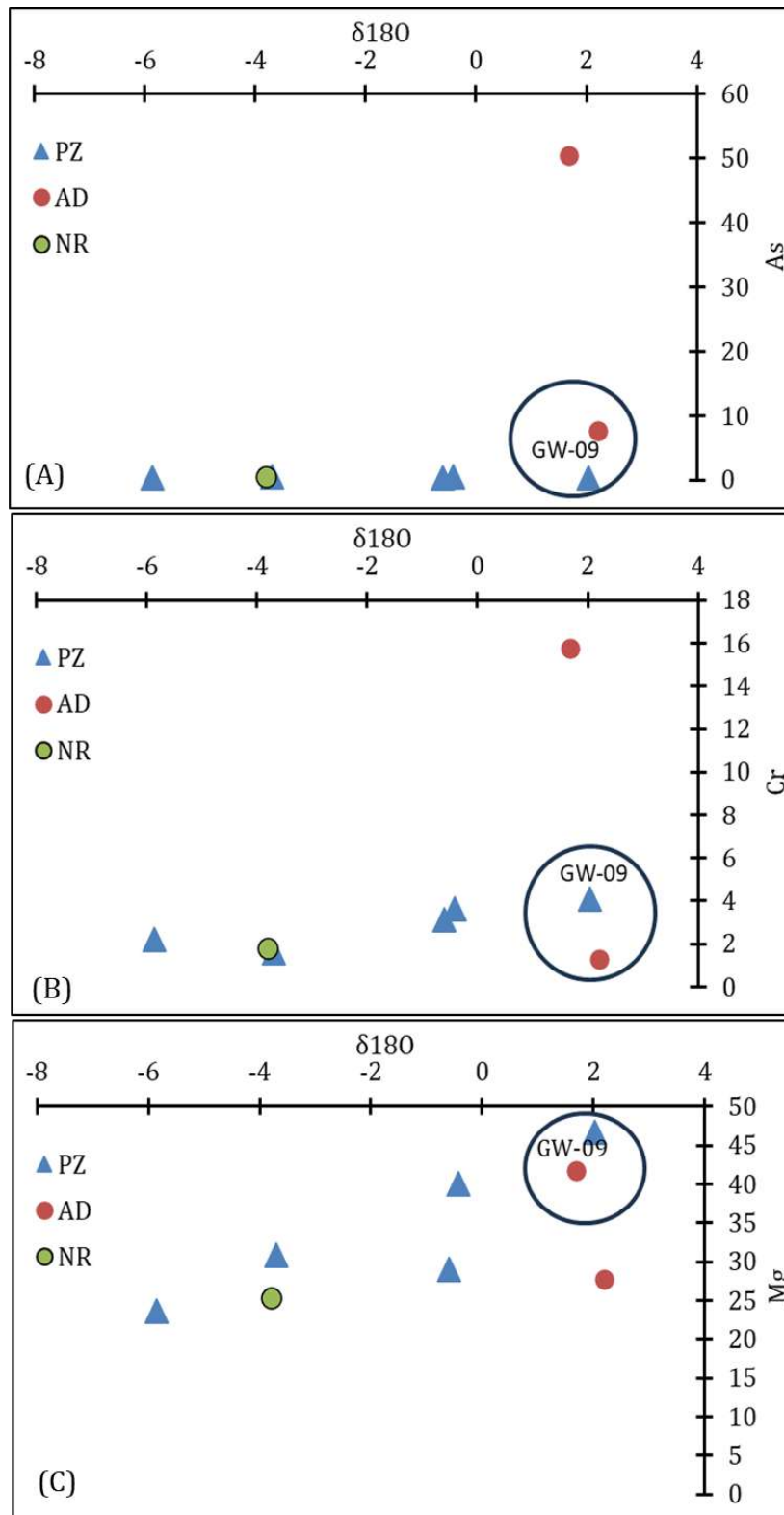


Figure 55: (A) $\delta^{18}O$ vs As (B) $\delta^{18}O$ vs Cr, and (C) $\delta^{18}O$ vs Mg plot for Piezometer (PZ) (pre monsoon), Narmada River (NR), and Ash dyke (AD) in the study area



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The cross plots $\delta^{18}\text{O}$ vs. Ca, NO_3 , EC, As, Cr and Mg (**Figure 55**), representing a distinct signature of isotopic characteristics in the groundwater, lagoon water, and River water within the buffer zone. Whereas, the lagoon water GW-09 (Piezometer - 01) is in close proximity to the lagoon water.

7.3.2 Conclusions:

The isotopic investigation of surface water (lagoon water, Ponds, and River) and groundwater (including 6 piezometers around the NTPC lagoon area) samples does not indicate any interaction between the lagoon water. The piezometer (GW-09 or piezometer -01) has some proximity with the isotopic signatures of lagoon water; other piezometer water samples do not have lagoon water interaction. Moreover, in order to confirm any interaction between Lagoon water and the surrounding groundwater, more temporal and spatial sampling around the piezometer 01 is required.





8 SUMMARY

The integrated evaluation of physico-chemical parameters, major ions, trace metals, irrigation indices, and stable isotopic signatures of surface water and groundwater within the 10-km buffer zone of the NTPC Khargone Thermal Power Plant provides a coherent understanding of the regional hydrogeochemical regime and environmental compliance status. The synthesis clearly indicates that natural geogenic processes dominate water chemistry, and no discernible contamination attributable to plant operations is reflected in the monitored data.

Both surface water and groundwater systems are characterized by mildly alkaline pH, moderate electrical conductivity, and predominantly freshwater TDS levels, with all values lying within the BIS (IS 10500:2012) and WHO (2017) guideline limits for drinking water, except for a few non-potable piezometer locations (KGW-9 to KGW-14) that are not used for domestic supply.

Hydrochemical facies analysis using Piper trilinear diagrams reveals that groundwater is dominantly of the Ca–Mg–HCO₃ type, with subordinate Na–HCO₃ and Ca–Mg–SO₄–Cl facies. This pattern reflects carbonate dissolution, silicate weathering, and ion-exchange processes typical of alluvial and weathered hard-rock aquifers of the Narmada basin. Surface waters show comparable facies, with slightly enhanced Na–Cl/SO₄ signatures in managed and industrial surface waters, consistent with evaporation and controlled recirculation, rather than external contamination.

Gibbs diagrams further confirm that the hydrochemistry of both surface water and groundwater is primarily controlled by rock–water interaction and evaporation dominance, with no shift toward anthropogenic pollution control fields.

Irrigation suitability assessment using Sodium Adsorption Ratio (SAR), electrical conductivity, and USSL classification indicates that:

- Groundwater samples predominantly fall within C2–S1 and C3–S1 classes, indicating medium to high salinity but low sodium hazard, suitable for irrigation on most soils with normal management practices.



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- Surface water samples, including ambient, managed, and industrial categories, also plot largely within low-sodium hazard (S1) fields, despite moderate salinity in some industrial/managed waters.

These results suggest that both groundwater and surface water are generally suitable for irrigation, and that observed salinity levels are attributable to natural concentration effects and evaporative enrichment rather than industrial effluent discharge.

Trace metal concentrations (As, Cd, Cr, Hg, Pb, Zn, Ni, Cu, Fe, Ba) in both surface water and groundwater exhibit clear spatial zoning, with comparatively higher values near piezometers installed around the ash dyke, as expected in controlled industrial settings. However, it is critical to note that:

- All trace metals in ambient groundwater and surface water remain within BIS, WHO, and CPCB permissible limits for drinking water and inland surface water use.
- Elevated iron and zinc concentrations at select village ponds and piezometers are consistent with natural lithology, redox conditions, and localized domestic inputs, and mirror baseline data reported earlier by NIH.
- Ash pond and piezometer waters comply with CPCB effluent discharge standards, and NTPC's Zero Liquid Discharge (ZLD) system ensures no off-site release of effluents.

No systematic enrichment, plume development, or downstream increase in metal concentrations is observed that could indicate leakage or contamination from plant operations.

Stable isotope analysis ($\delta^{18}\text{O}$ - δD) provides a powerful, independent line of evidence supporting the hydrochemical findings. Groundwater samples plot close to the Local/Indian Meteoric Water Line, indicating meteoric recharge origin with minimal evaporation prior to recharge. In contrast, surface water and ash dyke samples show enriched isotopic signatures, reflecting evaporation under open-water conditions.

Crucially, isotope cross-plots ($\delta^{18}\text{O}$ vs EC, Na, Ca, NO_3 , As, Cr, Mg) demonstrate distinct isotopic clusters for lagoon water, river water, and groundwater. Except for



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one piezometer (KGW-9 / PZ-01) showing partial proximity, no consistent isotopic mixing trend is observed between ash pond water and surrounding groundwater. This confirms that hydraulic and geochemical isolation of the ash dyke is largely effective, and there is no evidence of widespread lagoon-groundwater interaction.

The combined assessment of major ions, trace metals, irrigation indices, and isotopic tracers leads to a robust conclusion that:

- Water quality variations are controlled by regional geology, aquifer residence time, evaporation, and land-use practices, rather than industrial contamination.
- All potable and irrigation-relevant waters comply with BIS and WHO drinking water standards and CPCB environmental norms.
- The NTPC Khargone plant operations, supported by ZLD and controlled ash management, do not exert a measurable adverse impact on surface water or groundwater quality within the monitored buffer zone.

In summary, the integrated hydrogeochemical and isotopic evaluation unequivocally demonstrates that there is no pollution attributable to NTPC Khargone operations, and the observed water quality characteristics represent a natural, stable, and regulation-compliant hydrogeochemical system. Continued periodic monitoring, particularly near selected piezometers, is recommended as a precautionary best practice, rather than as a response to any detected environmental risk.



KIRAN SAINI Digitally signed by KIRAN SAINI
Date: 2026.03.28 13:50:47 +05'30'





प्रमाणपत्र ट्रैकिंग आईडी/Certificate Tracking ID : 2501844
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TC-11703



Radioanalytical Laboratory

RADIOACTIVITY TEST CERTIFICATE

Ref : BRIT/RAL/DOM/1787-1798/MISC/1392-1403/24-25

To :
M/S NTPC LIMITED (KHARGONE SUPER THERMAL POWER PROJECT)
PO.: SELDA, SO : BEDIYA, DISTT.KHARGONE,
MADHYA PRADESH - 451 114.

This is regarding the sample of "COAL, FLY ASH & BOTTOM ASH" sent for radioactivity analysis vide your letter Ref.no. NTPC/KGN/EMG/BRIT/2024-2025 dated 15.03.2025 as shown in italics:

Sr. No	SAMPLE DESCRIPTION	SAMPLE LOCATION	SAMPLING DATE
1	COAL	FEEDER, UNIT-2	04/03/2025
2	FLY ASH	UNIT-1	05.03.2025
3	BOTTOM ASH	UNIT-1	05.03.2025

DATE OF RECEIPT OF SAMPLE: 22.03.2025

DATE OF COMPLETION OF TEST: 15.04.2025

The samples were analysed for U-238, Ra-226, Th-232 and K-40 radioactivity content by HPGe gamma spectrometry and the values obtained are as follows:

Sr. No	NAME OF THE PRODUCT	U-238 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
1	COAL	43.7 ± 2.3	26.2 ± 4.1	78 ± 4.6	157 ± 10.8
2	FLY ASH	76.5 ± 2.5	73.3 ± 6.2	126 ± 4.2	301 ± 14.8
3	BOTTOM ASH	72.3 ± 2.8	68.7 ± 6.9	132 ± 8.4	320 ± 17.2

Opinion: The measurement values are below the clearance level for radionuclides of natural origin in bulk solid materials, as per AERB directive 01/2010 (table-3) dated 26/11/2010.

Note: (i) The report pertains to the given sample only. (ii) The sample will be retained in this laboratory for a period of 1 month from certificate date and thereafter it will be disposed off. (iii) This report shall not be reproduced except in full, without written approval of the laboratory. (iv) The sampling is not done by this laboratory.

Checked by:
GANPAT B NAKTI
Assistant

Authorized Signatory:
AJAY NANA THAMKE
OIC, RAL

***** End of Report *****

1/1

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Annexure-5

CSR Works by NTPC-Khargone STPS

FY: 2025-26 (October 2025-March 2026)

Initiation of MMU (Mobile Medical Unit) under Healthcare for PAVs and Vicinity Villages.



Dressmaking, Plumbing, Office work and CCTV camera training to Youth and Women of PAVs:



Organization of Oral Hygiene Camps for PAV schools:



Organization of Divisional level Handball at NTPC Khargone Stadium in which more than 600 students participated.



Inauguration and handing over of Govt Middle School Dalchi along with school Furniture.



Distribution of Aids and Appliances to Divyangs of Jhirniya and Bhagwanpura blocks:



Initiation of Medical Mobile Unit to provide free medical services to villagers



Skill Development Training to Women: Dressmaking and stitching and CCTV Installation and Maintenance



Provision of Solar Panels in Jhirniya and Bhagwanpura block





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**Social Impact Assessment
of
R&R & Community Development Projects for
NTPC Khargone
2022**

Disclaimer

This report is based on the social impact assessment survey conducted for community development programme of NTPC Khargone. The information contained in the report is of general nature and will not be intended to address the circumstances of any particular individual or entity. Recommendations and Comments in our report are not intended, nor should they be interpreted to be a binding opinion. IICA does not undertake any responsibility arising in any way whatsoever, to any person other than NTPC Khargone in respect of the matters dealt with in this report, including any errors or omissions therein, arising through negligence or otherwise, howsoever caused.

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ACKNOWLEDGEMENTS

The development be it social, economic or political, does not happen in isolation. The actual development is possible when all the efforts are converged and every one works together in order to release measurable social impact. Corporate Social Responsibility is a way to put additional efforts to provide impetus to the development of the country and its people. NTPC Khargone has been implementing CSR-CD activities in its peripheral villages and trying to improve the quality of life in the villages.

This report is an outcome of the social impact assessment survey undertaken by the Centre for Excellence in CSR and Corporate Citizenship, Indian Institute of Corporate Affairs. The study was undertaken with the cooperation and support of the officials of NTPC Khargone.

We would like to extend our sincere thanks to NTPC Khargone and its officials involved in the study. This could not be possible without their coordination and constant support. We are also thankful to the field co-ordinators and data enumerators for conducting the field survey. We also owe gratitude to the respondents of the survey, people of the villages and the village heads for their support and facilitation of the survey.

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LIST OF ACRONYMS

AWW KII	Anganwadi Worker Key Informant Interview
BPL	Below Poverty Line
CSR	Corporate Social Responsibility
CSR-CD	Corporate Social responsibility- Community Development
IMR	Infant Mortality Rate
KII	Key Informant Interview
MMR	Maternal Mortality Rate
NA	Data not available
NSO	National Statistical Organisation
PHC	Primary Health Centres
RGI	Registrar General of India
SHG	Self Help Group
KgSTPP	Khargone Super Thermal Power Plant
FGD	Focused Group Discussion
GEM	Girl Empowerment Mission
IICA	Indian Institute of Corporate Affairs
SROI	Social Return on Investment



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1. SOCIAL IMPACT EVALUATION OF R&R & COMMUNITY DEVELOPMENT PROJECTS NTPC KHARGONE

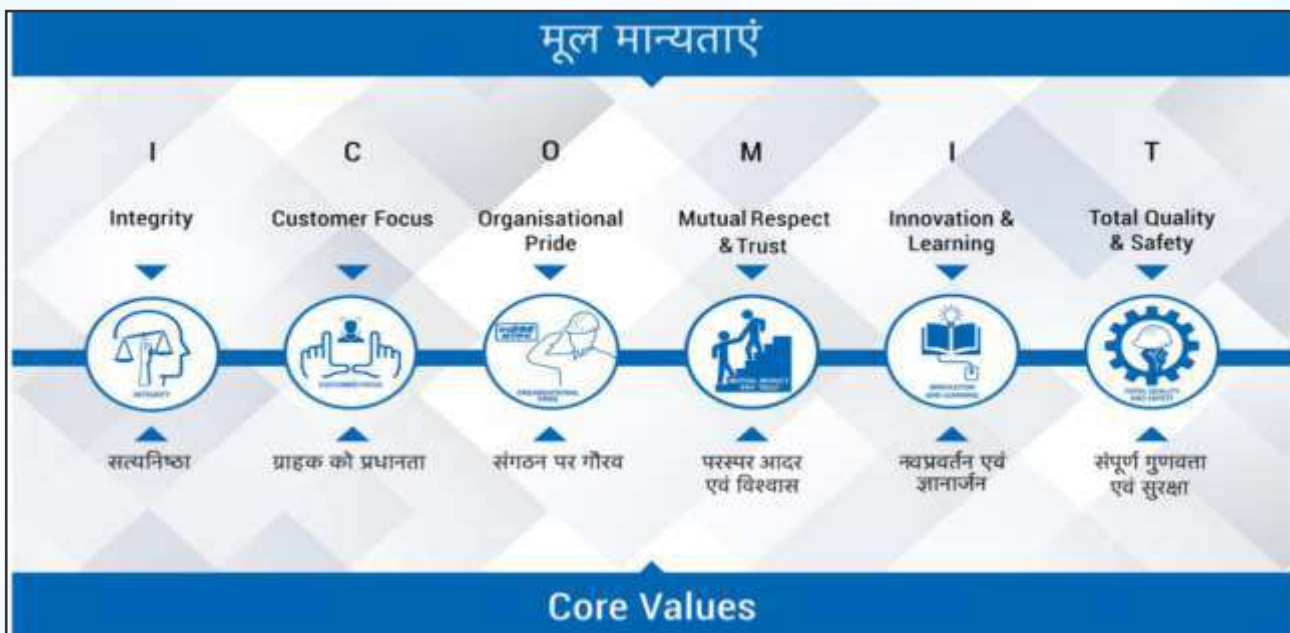
INTRODUCTION

1.1 NTPC & ITS APPROACH TO R&R & COMMUNITY DEVELOPMENT

NTPC is India's largest energy conglomerate with roots planted way back in 1975 to accelerate power development in India. Since then, it has established itself as the dominant power major with presence in the entire value chain of the power generation business. From fossil fuels it has forayed into generating electricity via hydro, nuclear and renewable energy sources. This foray will play a major role in lowering its carbon footprint by reducing greenhouse gas emissions. To strengthen its core business, the corporation has diversified into the fields of consultancy, power trading, training of power professionals, rural electrification, ash utilization and coal mining as well.

NTPC envisions to be the world's leading Power Company, energizing India's growth through providing reliable power and related solutions in an economical, efficient and environment friendly manner, driven by innovation and agility.

Figure 1 : Core Values of NTPC



(Source: NTPC)

NTPC's approach to Rehabilitation & Resettlement (R&R) is aligned well to its core business of setting up power projects and generating electricity. In accordance with its Rehabilitation and Resettlement Policy 2017¹. NTPC focuses on implementing Community Development (CD) programmes in the affected/neighbouring villages around its operating stations. Initial Community Development (ICD) Policy is implemented in close cooperation with the concerned state Authority in the areas identified for settling up the Greenfield/ expansion projects. These CD activities are project specific aimed to address local social issues in PAFs and promote positive dialogue and confidence of all project stakeholders. After the completion of R&R Policy, the community development activities are being planned to be continued under Corporate Social Responsibility- Community Development (CSR-CD).

¹ https://www.ntpc.co.in/sites/default/files/r_r_policies/NTPC-R-R-Policy-2017.pdf



NTPC Khargone has completed the CD interventions in PAVs under R&R policy in its vicinity villages. Hence, the Social Impact Evaluation (SIE) of R&R activities and SROI for CSR-CD were commissioned to IICA.

NTPC endeavours to minimize the acquisition of prime agricultural land and avoid acquisition of homestead as per its policy in the first place. The Project Affected Families (PAFs) are subject to both compensation and R&R benefits in a transparent manner. NTPC follows a consultative approach in its design and implementation of R&R and Community Development (CD) programmes. NTPC also supports institutionalizing the process of its R&R and CD activities that are monitored and evaluated through research studies.

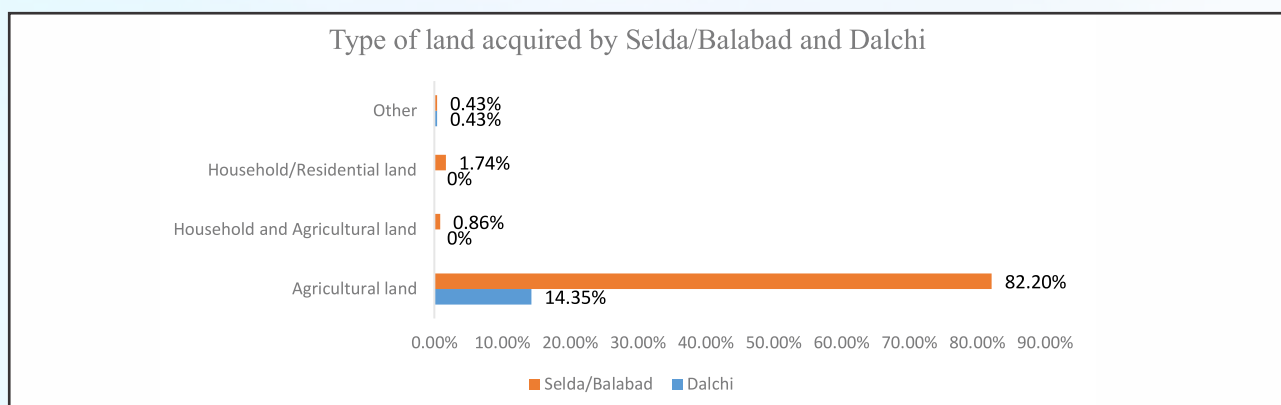
1.2 TYPE OF LAND ACQUIRED BY NTPC KHARGONE IN SELDA/BALABAD AND DALCHI

The construction of the NTPC Khargone plant affected two Gram Panchayat namely Selda/Balabad and Dalchi. A total of 357 persons were directly affected by NTPC Khargone's project, henceforth referred as the Project Affected Persons (PAPs).

Out of the 357 Project Affected Persons, only 244 could be contacted for interview. Rest of the PAPs had migrated to other locations and were untraceable. Also, their contact numbers were unavailable to the survey team. Out of the 244 PAPs spread across Selda and Dalchi, 230 people said that land was taken from them. Agricultural land was taken away from 222 people, followed by household land and agricultural land taken away from 2 people, and household/residential land was taken away from 4 people. Also, there were 2 people who said that some of their land was taken away but it was neither residential nor agricultural type of land.

The following figure represents the type of land acquired by NTPC Khargone from the PAPs who could be interviewed during IICA survey conducted in Selda/Balabad and Dalchi Gram Panchayat. As can be seen from the figure below, the majority of land that was acquired by NTPC Khargone happened to be agricultural land.

Figure 2: Type of land acquired by NTPC Khargone



Source: IICA Survey, 2022.

Furthermore, as mentioned in the Socio-Economic Study for KgSTPP, 2011 and as per the NTPC R&R policy (June, 2010), the number of Homestead Oustees was nil. This meant that none of the PAPs lost any residential structure.

2. RESEARCH METHODOLOGY

Indian Institute of Corporate Affairs (IICA) has conducted the social impact evaluation study including the social return on investment in the Project Affected Villages (PAVs) around NTPC Khargone. IICA follows a systematic process for determining and addressing needs, or “gaps” between current conditions and desired conditions. The SIE component of the study would measure the social, educational, economic, and cultural impacts of R&R & CD activities of the projects of NTPC Khargone. A community level situation for impact has been assessed in the broad areas of Education, Vocational Training, Healthcare, Water and Sanitation, and Rural Infrastructure. The Impact assessment study was conducted in the following Gram Panchayat of Khargone district of Madhya Pradesh.

Table 1: List of Gram Panchayat

Village/ Gram Panchayat Name	Distance in kms from NTPC Khargone Plant
Selda/Balabad	2 Km (Approx.)
Dalchi	4.5 Km (Approx.)

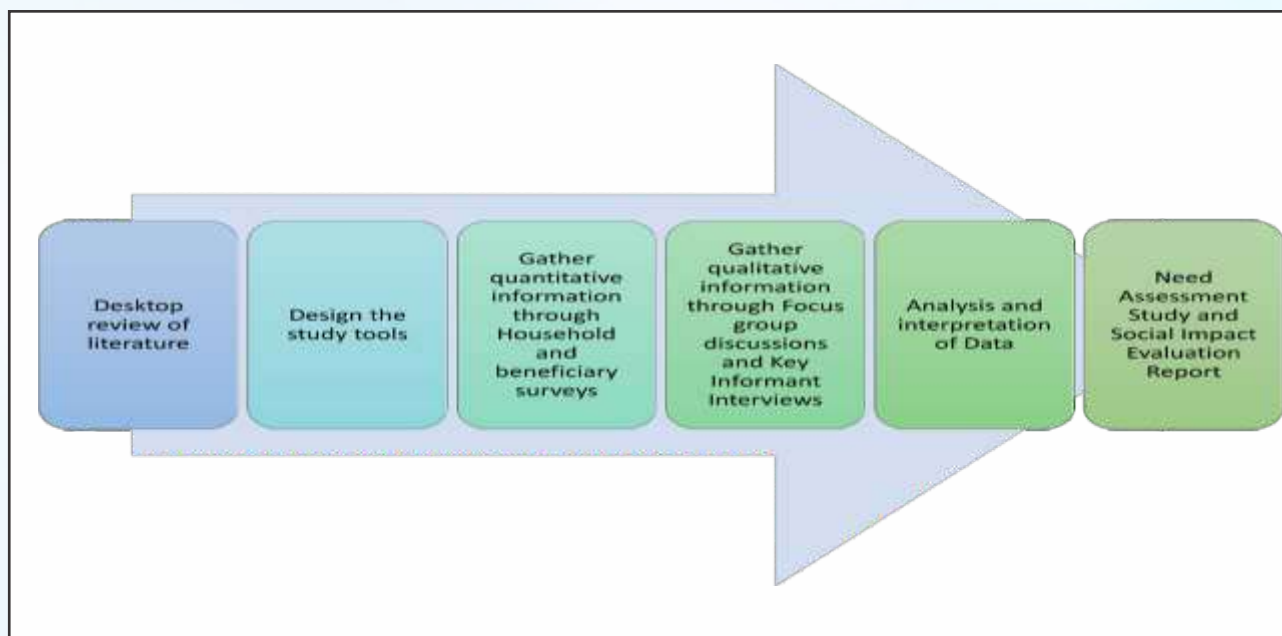
(Source: IICA Survey, 2022)

2.1 RESEARCH METHOD AND SAMPLING

The study employed both primary and secondary data. Primary data was collected through fieldwork in two-gram panchayats/villages named Selda/Balabad and Dalchi. These two gram panchayats comprise 13 hamlets. While Selda has 5 hamlets, Dalchi has 8 hamlets.

To conduct the SIE study, IICA adopted a six-step approach as explained in Figure 4

Figure 3: Research Steps adopted in the study



The first step was to collate Secondary data from different government sources (including websites, indices, and publications) and preparing a stakeholder map against the themes of the project. The second step was to prepare, pre-test and finalize the Research Tools for the field survey. The third step was to assemble a survey team and prepare them for the field survey in the two Gram Panchayats. As the fourth step, Focus Group Discussions (FGD) was held for the collection of qualitative information regarding the village. Fifth, data analysis of findings and preparation of the preliminary evaluation was done. The last step is the finalization of the report and reporting of conclusions and recommendations.



Table 2: Stakeholder mapping to understand Project outcomes

Education	Vocational Training	Health care	Water & Sanitation	Rural Development
Gram Panchayat	Gram Panchayat	Gram Panchayat	Gram Panchayat/ Village Water & Sanitation Committee	Gram Panchayat
NTPC Officials	NTPC Officials	NTPC Officials	NTPC Officials	NTPC Officials
Students	Farmers & Youth	Community members	Community members	Community members
Parents of children attending schools	Community Members	Local Doctors	Health and Sanitation Worker	Construction workers
School Officials (principal & teachers)	Skill Trainer	District Officer of Health (DoH)		Village Development Advisory Committee
School Management Committee	Family Members of trainees	AWW/ ASHA/ ANM		AWW/ Veterinary Doctor
Block Education Officer				
District Education Officer				
Village Development Advisory Committee				

To understand the impact of the interventions undertaken by NTPC Khargone, the primary data was collected through household surveys, focus group discussions and key informant interviews.

Overall, the total sample size happened to be 680 which include 648 Beneficiary survey and 32 Key Informant Interviews. Additionally, several villagers participated in the study through 13 FGDs.

The household survey covered questions regarding the significant domains such as education, vocational training, infrastructure, health, drinking water & sanitation. Additionally, the survey analyses the attitude, knowledge and behaviour of the locals/communities.

Secondary data was collected from the Census of India (2011), government reports and official records of various offices like Panchayati Raj Institution, Anganwadi Centres and Schools apart from the data received from the NTPC office. Data collected through quantitative questionnaires was analysed using Microsoft Excel and qualitative tools like FGD and KII were analysed through description and explanation.

A proportionate stratified sampling was undertaken to identify the size of the sample from each of the two gram panchayat. This was done to ensure that the size of the sample strata was proportional to the size of the population strata. Further, there were two categories of participants spread across the two-gram panchayat. One of the categories belonged to Project Affected Persons (PAPs) and the other included the Non-PAPs. While a simple random sampling technique was used to select non- PAP households from the hamlets under each of the main village/gram panchayat i.e. Selda and Dalchi, a purposive sampling technique was used to cover the PAPs for the impact evaluation study. The list of the PAPs was provided by NTPC Khargone. However, as some PAPs could not be traced due to the latter's migration; the non-PAPs households were selected at their place in order to meet the required sample size of the study.

3. TARGET AREA PROFILE

The current study of Social Impact Evaluation has been conducted in two Gram Panchayat namely Selda/Balabad and Dalchi in Khargone district of Madhya Pradesh.

History: The District of Khargone is in the Madhya Pradesh state in India's central region. Khargone was previously known as West Nimar. Functional offices i.e. police station, the collectorate office, telecom and other government organisations are located in the district headquarter i.e. in the town of Khargone. Cotton and chilly are grown on the banks of river Kunda. The people of Khargone speak Namadi as its primary language in west Nimar, Bareli and Palya.

Geography: The Khargone district spans 8,030 km² (3,100 sq mi). The district is located between 74°25' and 76°14' east longitudes and latitudes between 21°22' and 22°35' north. The district is bordered by the districts of Dhar, Indore, and Dewas in the north; the state of Maharashtra's Jalgaon District in the south; the districts of Khandwa and Burhanpur in the east; and the districts of Barwani in the west.

Image 1: Demographic profile of the survey area



The village-wise demographic distribution of the population of the selected villages is given below

Table 3: Basic Demographics of selected villages/Gram Panchayat village

Indicator to measure keeping objective	India	Madhya Pradesh	Khargone	Selda/Balabad	Dalchi
Total Population	1210854977	72626809	1873046	2569	1643
Male	623270258	37612306	953121	1338	890
Female	587584719	35014503	919925	1231	753
Sex Ratio	943	931	965.17	92.02	972.08
SC	201378372	11342320	209091	247	75
ST	104545716	15316784	730169	201	553
Number of infant (age of 0-6)	163819614	10809395	299990	228	283

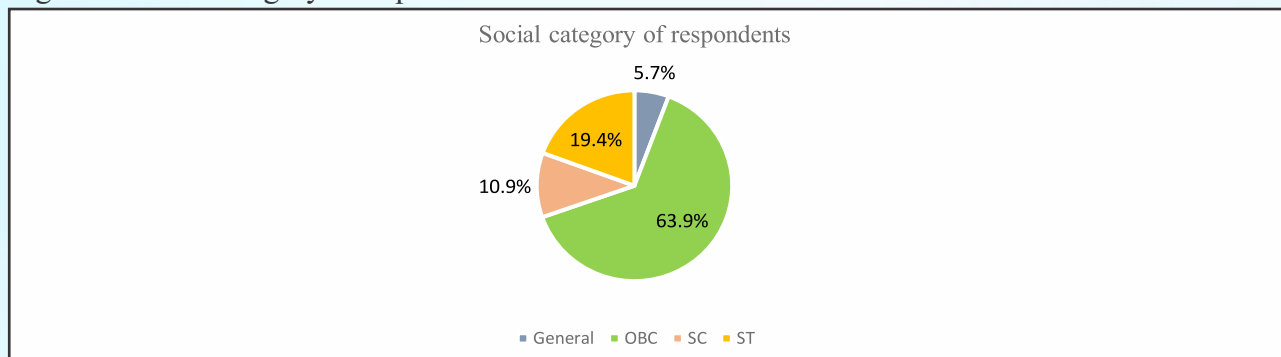
(Source: Census of India, 2011 and data received from NTPC Khargone)



Social category of respondents

It is reported that 63.9 percent of the respondents belong to the OBC category. While 10.9 percent of the respondents also come from the schedule caste background, 19.4 percent of the respondents belong to the scheduled tribe category.

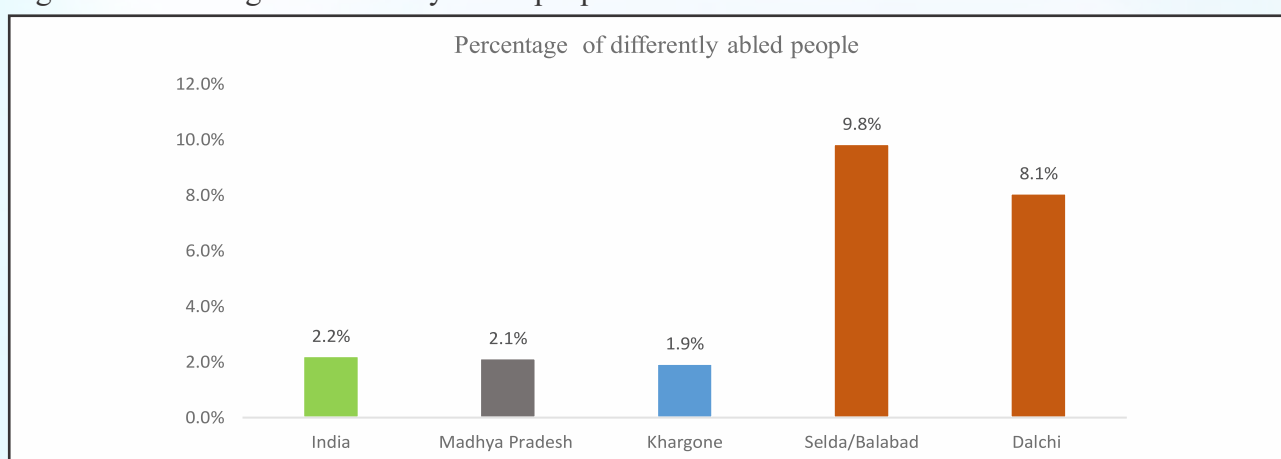
Figure 4: Social category of respondents



Percentage of differently-abled people

The percentage of differently-abled people at Selda/Balabad (9.8%) is higher when compared to the Dalchi gram panchayat (8.1%). It is also quite evident that the percentage of differently-abled people at both the gram panchayat is higher than the national (2.2%), state (2.1%) and district (1.9%) benchmark.

Figure 5: Percentage of differently-abled people



(Source: IICA Survey, 2022)

3.1 EDUCATIONAL STATUS

Literacy rate

The average literacy rate of India according to Census of India, 2011 was 72.98 % while it was pinned to 77.7 % in 2017-18 by National Sample Survey².

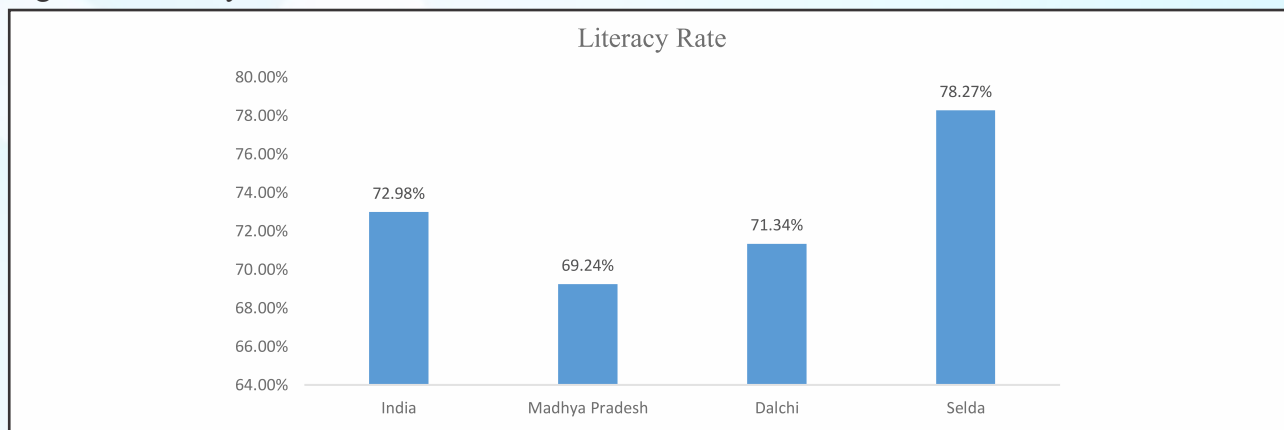
As mentioned in the Socio-Economic study for KgSTPP, 2011, the overall literacy rate in the PAVs was about 67.44%. Literacy is the ability to read and write only (and not educated). Following this definition of literacy, IICA Survey, 2022 found that 19.29% of the sample population were able to read and write only.

However, while mentioning the overall literacy of the sample population, IICA survey, 2022 has considered not only those who are able to read and write but also those who are educated further and have studied in school and college. Therefore, the overall literacy rate of the sample population in the PAVs (Selda/Balabad and Dalchi) was found to be 74.69%.

² Census of India, 2011

A Gram Panchayat- wise analysis found that the level of literacy in Selda/Balabad is 78.27% while the literacy rate of Dalchi is 71.34% .The literacy rate of Dalchi (71.34%) is higher than the state benchmark (69.24%)but is slightly lower than the national bench mark (72.98%). The literacy rate of Selda/Balabad (78.27%) is higher than the state(69.24%) and national benchmark (72.98%). Therefore, it shows that the overall percentage of literate people(including educated) in the PAVs have improved from 67.44% (2011) to 74.69% (2022) after NTPC Khargone's interventions.

Figure 6: Literacy Rate



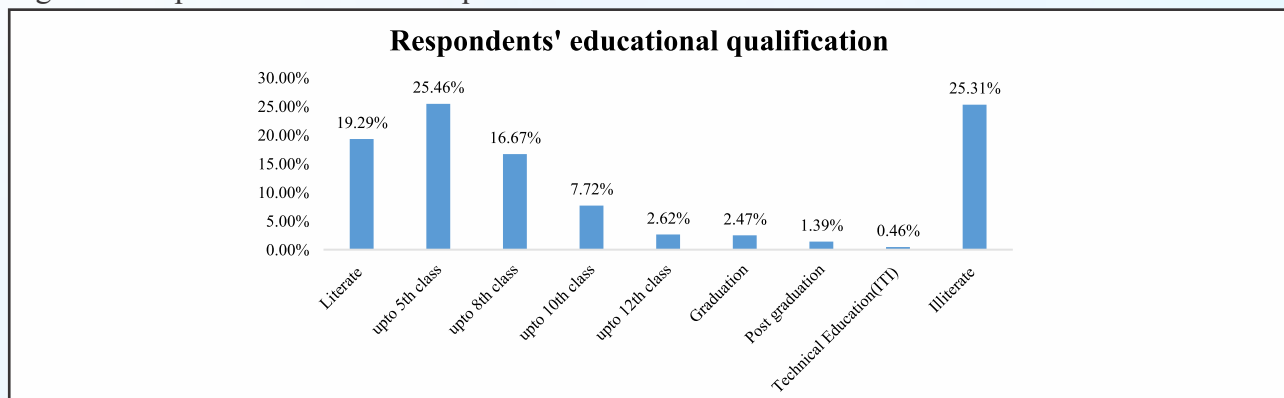
(Source: Census 2011 and IICA Survey, 2022)

Respondents' educational qualification

Figure below shows an analysis of the educational qualification of the surveyed respondents in Selda and Dalchi revealing that the maximum percentage of respondents had studied up to 5th class(25.46%), followed by respondents who are illiterate (25.31%), respondents who can read and write only (19.29%), respondents who had studied up to 8th class (16.67%), respondents who had studied up to 10h class (7.72%), respondents who had studied up to 12th class (2.62%), respondents who are Graduates (2.47%), and respondents who are post graduates (1.39%).

By technical education, it is meant the training received in ITI (as ITI is a technical course). It was found that 0.46% of respondents had received technical education/ITI. As per the data received from NTPCKhargone,600 beneficiaries from Selda, Dalchi and Khedi Panchayat were provided skill development training and the local villagers are engaged for contractual jobs which are technical in nature.

Figure 7: Respondents' educational qualification



(Source: IICA Survey, 2022)

Gender-wise educational qualification (%)

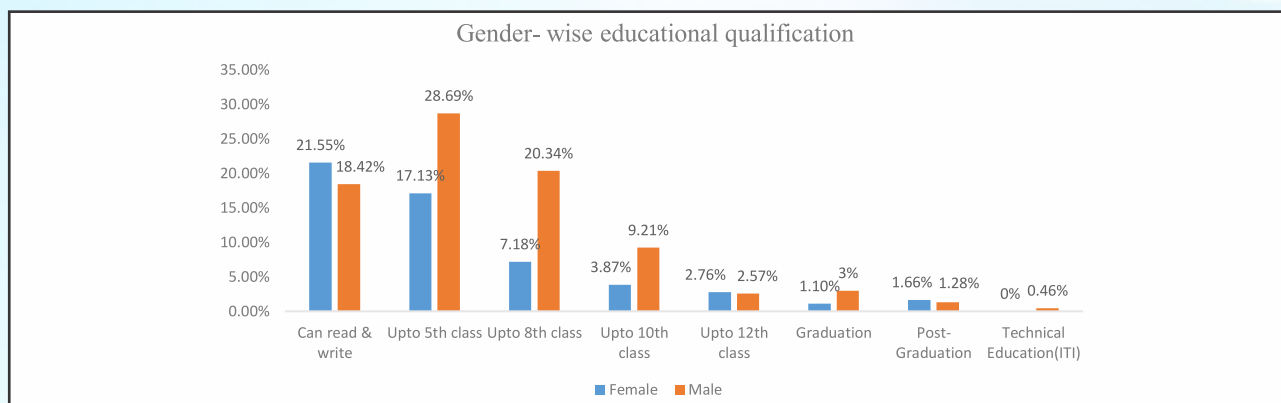
Out of the total number of surveyed households (648) spread across Selda and Dalchi Gram Panchayat, in 27.9% of the households, the females participated in the interviews conducted by IICA while in 72.1% of the households, the males participated in the interviews. The educational qualifications of the female respondents were analyzed separately from the male respondents.



The survey also found that the women lag behind men in receiving school and college education. As can be seen, while 17.13% of the women respondents have studied till 5th class, 28.69% of the men respondents have studied till 5th class. Similarly, only 7.18% of women respondents have studied till 8th class as against 20.34% of the male respondents. Furthermore, only 3.87% of the female respondents could complete their matriculation in comparison to 9.21% male respondents. Also, at the higher educational level such as graduation, the women lagged behind men. Moreover, with respect to technical education like ITI, there were no women respondents.

Furthermore, as per the socio-economic study for KgSTPP conducted in 2011, the males were more educated than the females. This gap in education between men and women has more or less remained the same in 2022 as found during IICA survey.

Figure 8: Gender wise educational qualification

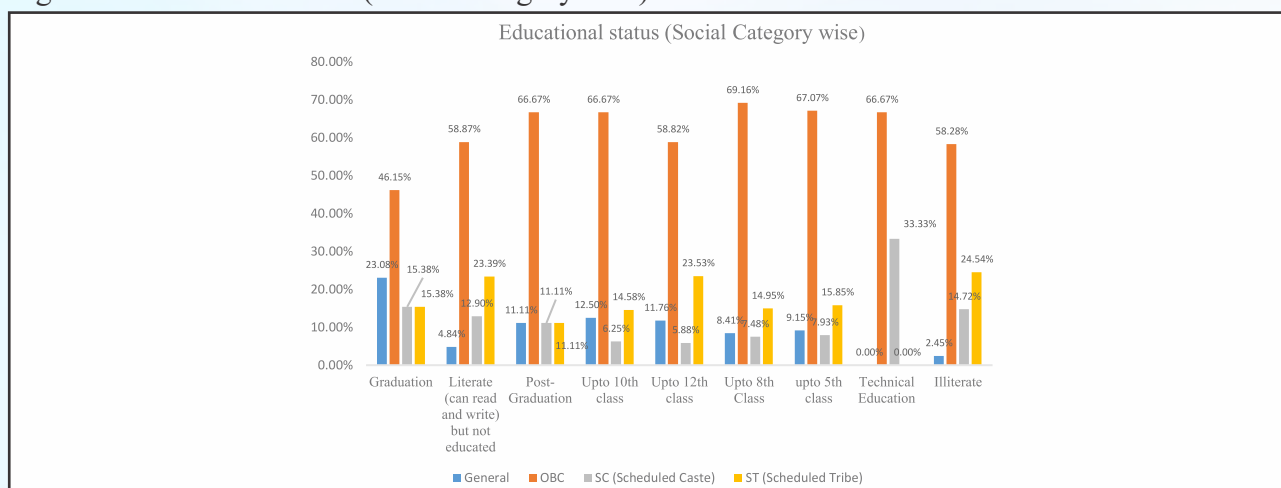


(Source: IICA Survey, 2022)

Educational status social category wise

As also discussed earlier (Figure 5), the maximum number of participants of the SIE study conducted by IICA belonged to the OBC category (63.9%), therefore, an analysis of the social category wise educational status of the respondents revealed that the maximum number of graduates, illiterates as well as those who received technical education were also from the OBC category.

Figure 9: Educational status (Social Category wise)

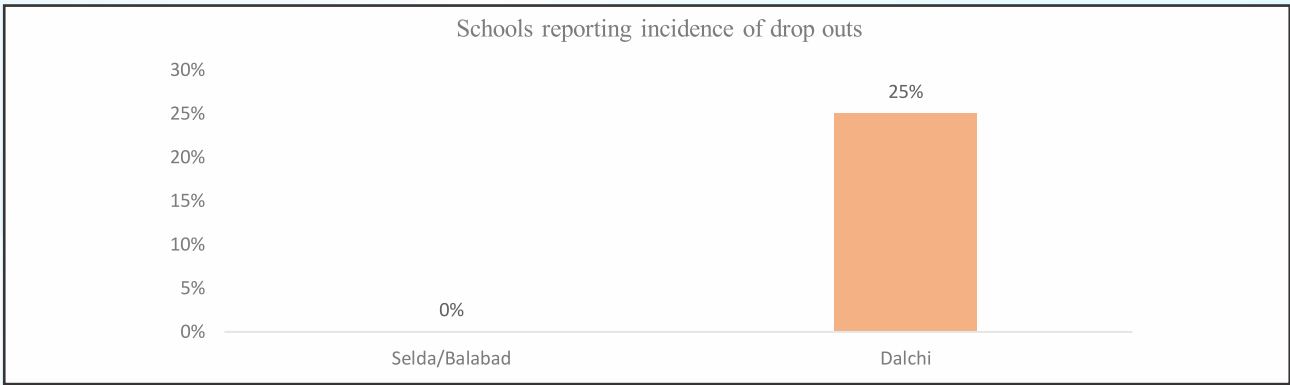


(Source: IICA Survey, 2022)

School dropout incidence

A total of nine schools were surveyed in Selda/Balabad and eight schools in Dalchi. The list of the schools to be surveyed was provided by NTPC Khargone. It was found that none of the schools in Selda/Balabad reported any incidence of school dropout, however, two schools at Dalchi reported that few students had to drop out due to migration. The following figure shows that 25% of the surveyed schools in Dalchi Gram Panchayat reported incidence of school dropout.

Figure 10: Schools reporting incidence of dropout



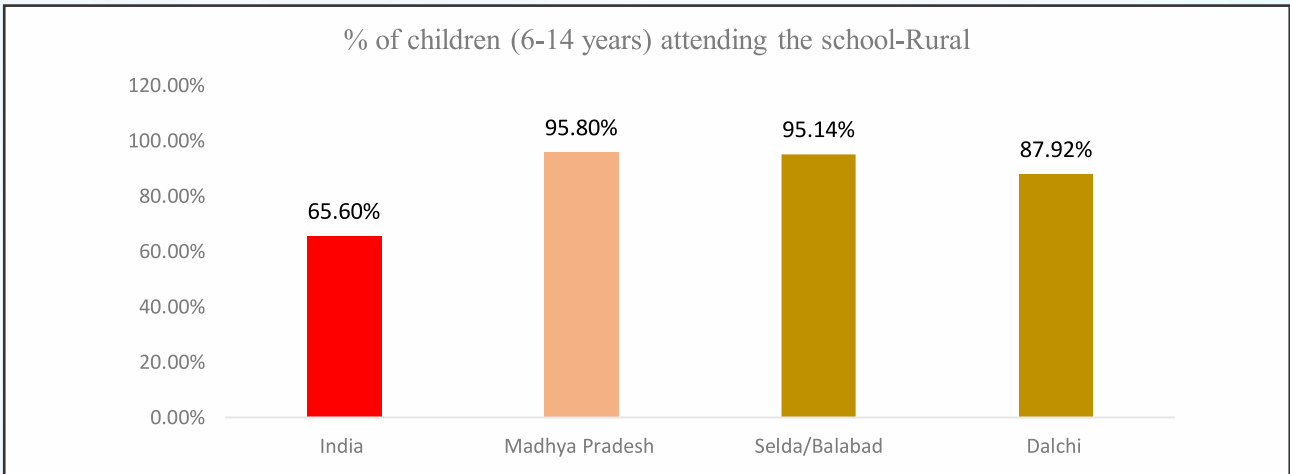
(Source: IICA Survey, 2022)

Percentage of children (6-14 years) attending the school-Rural

Any society's foundation is built on education. The quality of education being delivered is a key factor in how society develops. Therefore, by promoting the holistic development of children, schools play a significant role in shaping that country's future.

The IICA survey suggests that 65.6 % of children in India between the age group 6-14 years attend school. 95.8 % of children in Madhya Pradesh between the age group 6-14 years attend school. It is also evident from the figure below that the percentage of school going children between the age group (6-14 years) from the sampled households in the study gram panchayat Selda/Balabad (95.14%) and Dalchi (87.92%) are above the national benchmark (65.6%) but below the state benchmark (95.8%)

Figure 11: Percentage of children (6-14 years) attending the school-Rural



(Source: IICA Survey, 2022)

Training and skills available to people

In rural India, developing skills is crucial. Through limiting their access to well-paying jobs, a lack of proper education and training prevents people from having opportunities for self-advancement. Thus, this prevents them from having opportunities in their lives to develop a fulfilling and healthy lifestyle as well as from having an impact on the economic growth of the country.

The IICA survey shows that 6.07 % of the respondents from Selda/Balabad and 6.57 % of the respondents from Dalchi gram panchayat have undergone some form of skill development training, out of which a total of 3.54% of the respondents did receive the skill development training through NTPC Khargone. The names/types of the trainings as reported by people are Stitching, Pickle, Papad, Beauty Parlour, Electrical, AC repair, Rakhi, Computer, and agriculture.



Figure 12: Training and skills



(Source: IICA Survey, 2022)

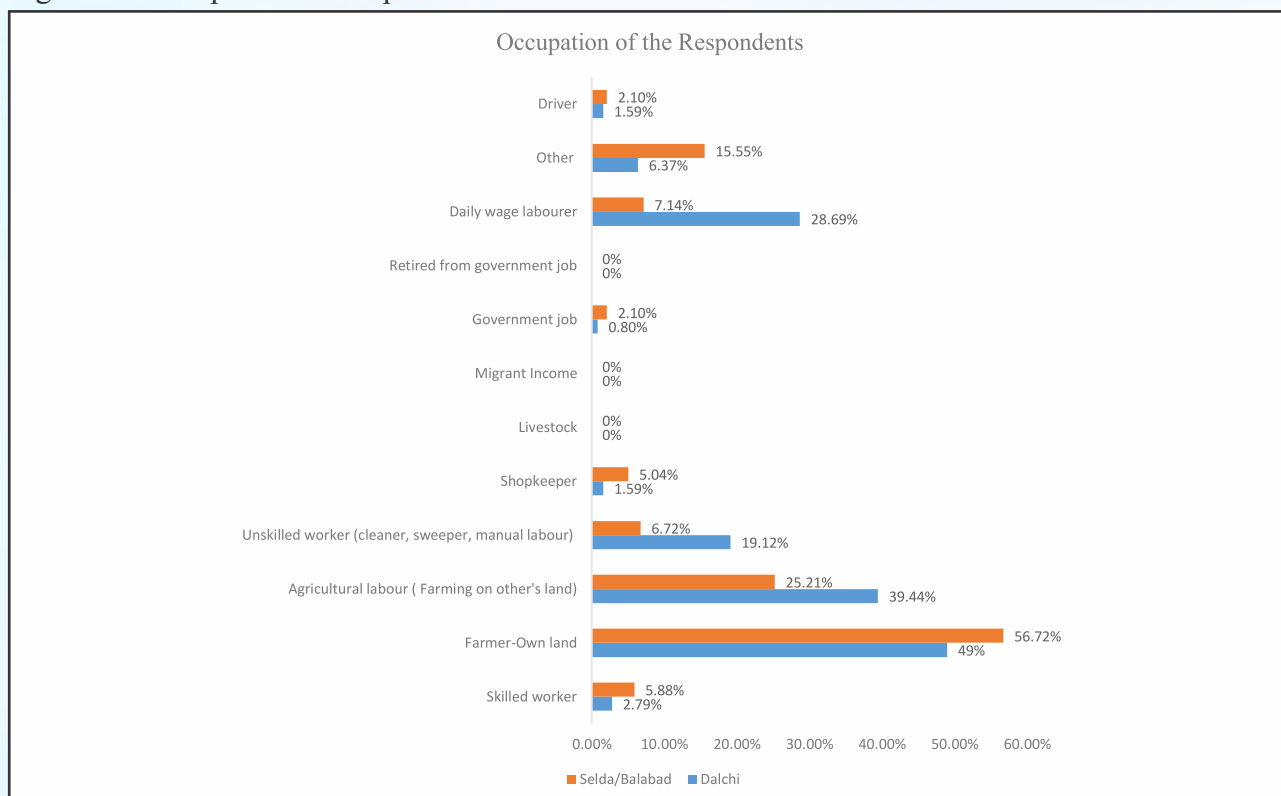
3.2 EMPLOYMENT STATUS

Employment is one of the critical issues in the rural communities. Employment and livelihood needs are major needs for the people in the rural areas.

Occupation of respondents

Figure below shows that there is a higher percentage of respondents from Selda/Balabad (5.3%) who are skilled workers as compared to Dalchi (2.2%). While the majority of the respondents in Selda/Balabad are engaged as farmers (51.5%) followed by agricultural labourers (22.9%), the majority of respondents in Dalchi are also engaged as farmers (37.8%) followed by agricultural labourers (30.5%). A small section of the respondents work in the dairy industry, coal factory, in a hospital as a doctor, and in a temple as a priest. 1.2 % of the surveyed respondents are employed in NTPC as cooks, cleaners and other manual labour work.

Figure 13: Occupation of Respondents

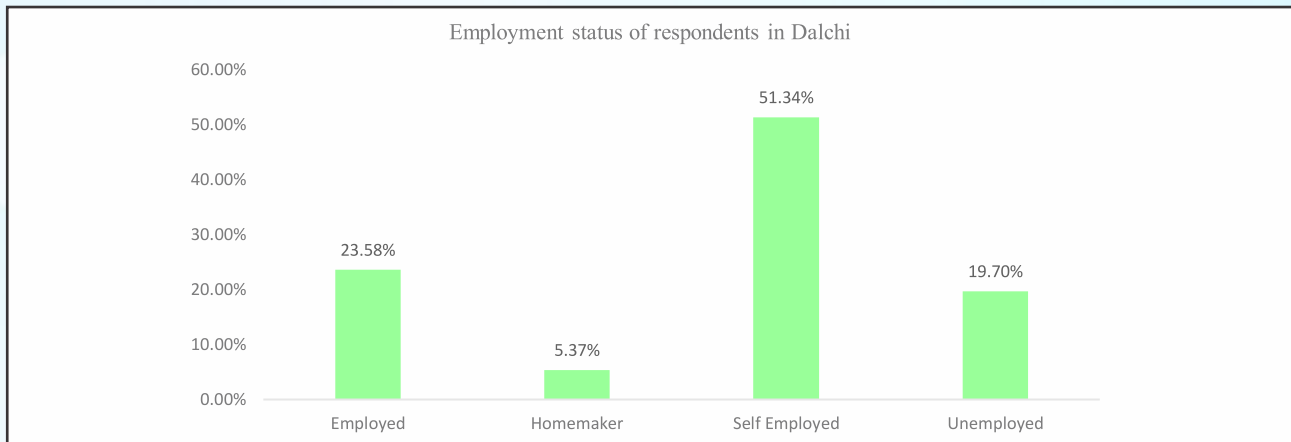


(Source: IICA Survey, 2022)

Employment status of the respondents

Figure below shows that 51.34 % of the respondents of Dalchi are self-employed. 23.58 % of the respondents are employed while 5.37 % and 19.70 % of the respondents remain as homemakers and unemployed respectively.

Figure 14: Employment status of respondents in Dalchi

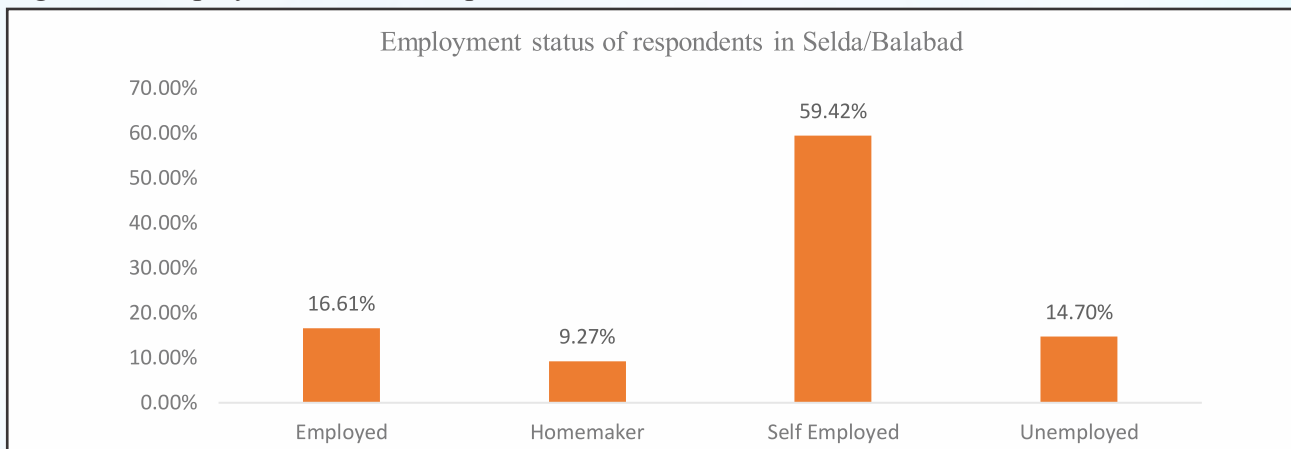


(Source: IICA Survey, 2022)

Employment status of Selda/Balabad

Figure below shows that 59.42 % of the respondents of Selda/Balabad are self-employed. 16.61% of the respondents are employed while 9.27 % and 14.70 % of the respondents remain as homemakers and unemployed respectively.

Figure 15: Employment status of respondents in Selda/Balabad



(Source: IICA Survey, 2022)

As per the socio-economic study for KgSTPP conducted in 2011, 52.6% population in the PAVs happened to be working and the remaining 47.84% was non-working population. The IICA survey, 2022 shows that overall 75.47% of the surveyed households spread across Selda/Balabad and Dalchi happened to be working (which includes 20.22% households as employed by others and 55.25% as self-employed). The total percentage of the non-working population was found to be 24.53% (which includes 7.25% as homemakers and 17.28% as unemployed). Therefore, it can be concluded that the percentage of working population in the PAVs have improved significantly in the past ten years i.e. from 2011(52.6%) to 2022 (75.47%) after NTPC Khargone's interventions.

Furthermore, the socio-economic study for KgSTPP in 2011 reveals that out of the total workers, 56.85% were cultivators, 37.49% happened to be agricultural labours, 0.33% were household workers and 2.32% other workers. The IICA survey, 2022 found that out of the total number of employed respondents in both Selda and Dalchi, overall 4.29% were skilled workers, 52.76% were farmers or



cultivators, 32.51% were agricultural labour, 13.08% were unskilled workers, 1.82% were daily wage labourers and 10.83% were engaged as other workers. The occupational pattern has also been analysed separately for Selda/Balabad and Dalchi (Figure 13).

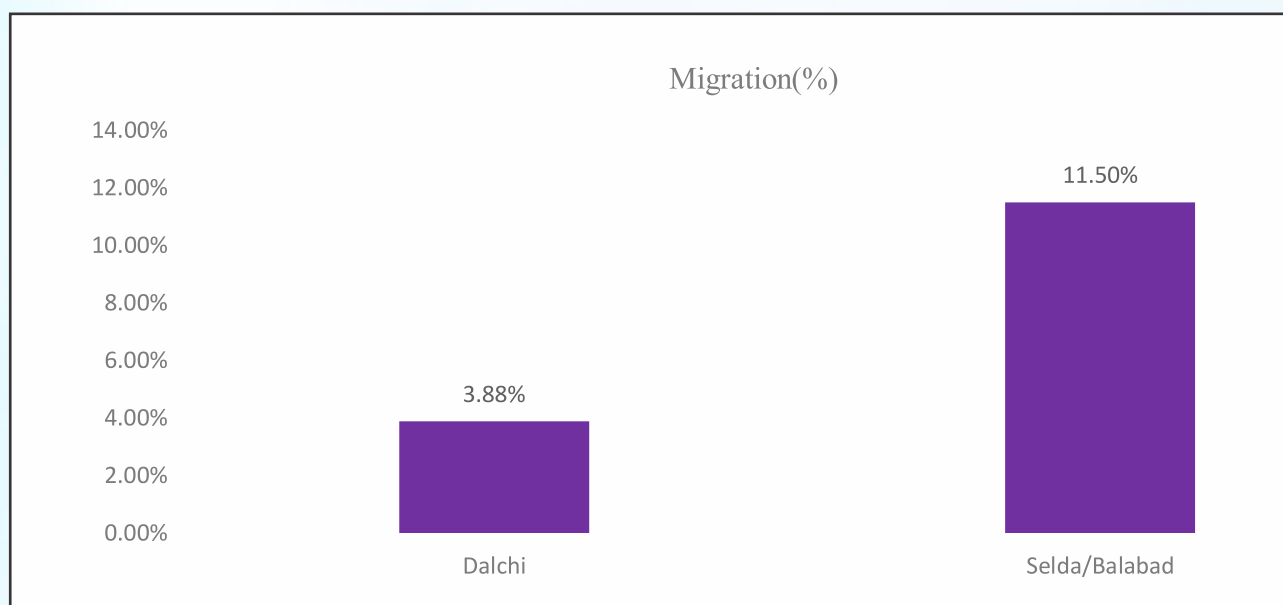
Therefore, it can be concluded that the percentage of farmers or cultivators have decreased in 2022 (52.76%) when compared with the baseline data in 2011 (56.85%). Similarly, the percentage of agricultural labour have also decreased in 2022 (32.51%) in comparison to the baseline data in 2011 (37.49%).

Migration

The search for better career opportunities and the lack of employment opportunities in the area are the primary reasons that have pushed people to other areas in search of employment.

Figure below suggests that Migration was observed to be higher in Selda/ Balabad (11.50%) while it was lesser in Dalchi (3.88%). During interaction with the community, the respondents revealed that people usually migrate to Mumbai, Maharashtra, and Indore, Madhya Pradesh in search of wage employment. However, as informed by NTPC Khargone, better opportunities of livelihood in different cities attract the agricultural labourer for a limited time period i.e. around three months after which they return. NTPC Khargone further informed that as per the government record, Selda/Balabad and Dalchi did not have permanent migration.

Figure 16: Migration (%)



(Source: IICA Survey, 2022)

3.3 ECONOMIC CONDITION

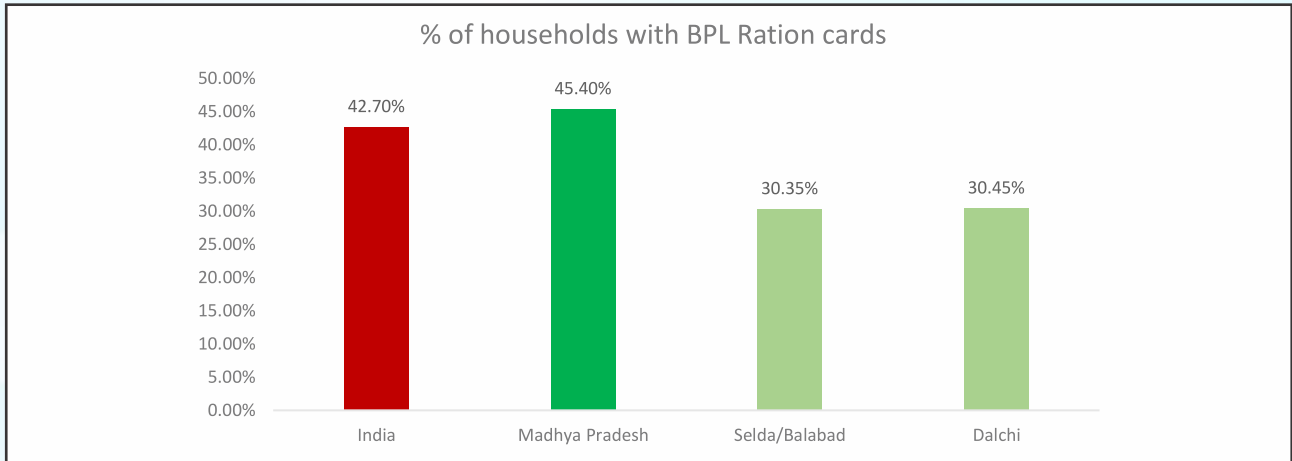
To understand the economic conditions of the respondents, the two most important indicators are population below BPL and per capita annual income.

BPL population

Out of the total population living in India, 42.7 % of them are living below the poverty line, and in Madhya Pradesh it is 45.4 %³. Figure 18 highlights that the economic conditions of the people in the study area are relatively better when compared with the national (42.7%) and state benchmark (45.4%). On asking about the BPL cardholders, it was found that a slightly higher percentage of households below the poverty line were found in Dalchi (30.45%) than in Selda/Balabad (30.35%).

³ Antyodaya Dashboard, 2019-20

Figure 17: BPL Population (%)



As informed by NTPC Khargone, a hefty compensation was provided to the Project Affected Persons (PAPs) much above the government rates. Further, in addition to the R& R grant, a lump sum amount was also given to the PAPs against non-availability of Jobs at NTPC Khargone. As per NTPC Khargone, post-land acquisition, 90 percent of the farmers could purchase a land which was double in size than they previously held.

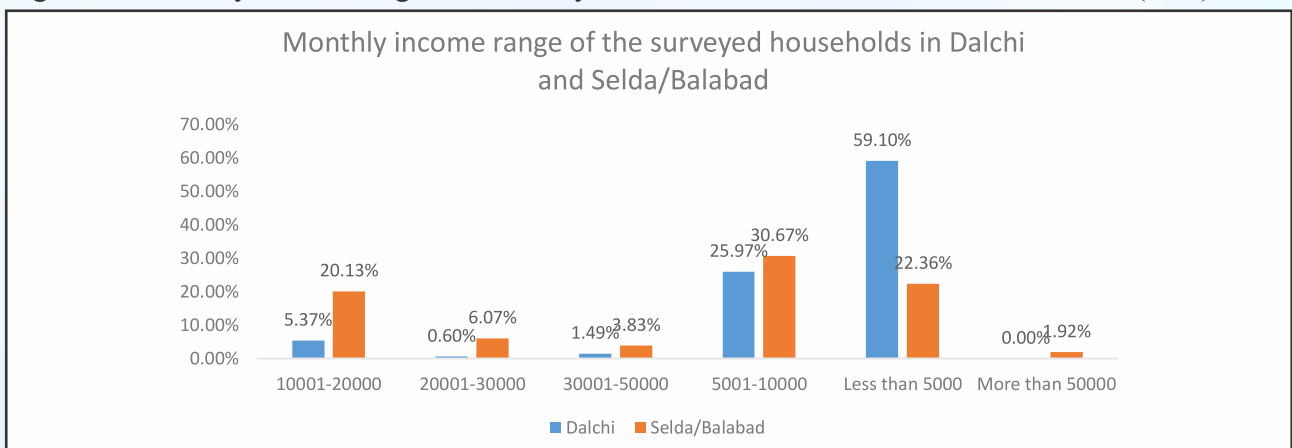
Monthly income range of respondents

As per the socio-economic study for KgSTPP in 2011, the annual household income varied between Rs. 20,000 and Rs. 5,00,000 per family. Therefore, on comparing the baseline data for annual income range with the IICA survey, 2022, it was found that the maximum annual income has increased upto Rs 6,00,000 and above (However, none of the surveyed households in Dalchi and only 1.92% of the surveyed households in Selda earned more than 50,000 per month or 6,00,000 Per annum).

Further, the minimum annual income as can also be observed from Figure 19 below, happened to be less than 60,000 per family. However, it is important to note here that the majority of the surveyed households in the study villages belong to this category of income (59.10% households in Dalchi and 22.36% households in Selda earn less than Rs 5000 per month or 60,000 per annum). Given the per capita income (NNI) of India being INR 94954⁴, it can be said that the majority of the surveyed households in the study area have a monthly income range below the national benchmark.

Nevertheless, 25.97% households in Dalchi and 30.67% households in Selda earn a monthly income between Rs. 5000-Rs 10000, 5.37% households in Dalchi and 20.13% households in Selda earn a monthly income between Rs. 10000- Rs. 20000, followed by 0.6% households in Dalchi and 6.07% in Selda earning a monthly income between Rs. 20000 -Rs 30000. Moreover, 1.49% households in Dalchi and 3.83% households in Selda have a monthly income range between Rs. 30000-Rs. 50000.

Figure 18: Monthly income range of the surveyed households in Dalchi and Selda/Balabad (INR)



(Source: IICA Survey, 2022)

⁴ <https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19735>

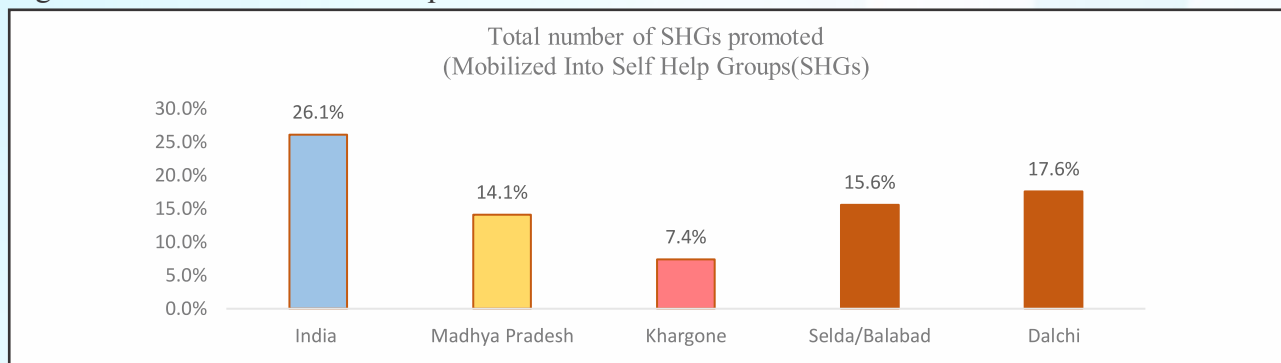


3.4 GENDER EQUALITY AND WOMEN EMPOWERMENT

Total number of SHGs promoted (Mobilized into Self Help Groups (SHGs))

The figure below indicates the formation of SHGs is higher in the study gram panchayat villages when compared to the district (7.4%) and state bench mark(14.1%) however the former is still less than the national benchmark (26.1%). More women-centric interventions need to be focused on the study gram panchayat to bring them to the national benchmark.

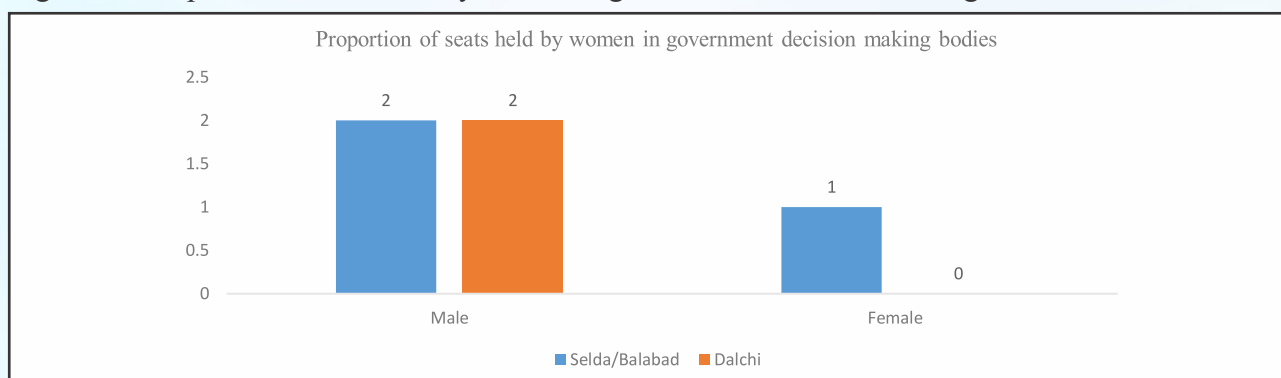
Figure 19: Total number of SHGs promoted



Proportion of seats held by women in government decision making bodies

According to Abraham Lincoln, a true democracy is a form of government that is run by, for, and by the people. For women's interests to be taken into account in governance, women must participate in decision-making. To create gender equal opportunities and gender sensitive policies, including women is crucial, especially in local governments. Women's needs and perspectives on social and political issues vary, so it is crucial to include them in governments in order to take into account all societal viewpoints when formulating policy and making decisions. As per IICA survey, key informant interviews were conducted with five Panchayat members. It is found that most of them are male candidates indicating low female participation in the area.

Figure 20: Proportion of seats held by women in government decision-making bodies



Source: IICA Survey, 2022)

3.5 HEALTH STATUS

Life expectancy

In 2013-2017, the life expectancy in Madhya Pradesh is 69 years. For men, it is 67.8 years and for females it is 70.4 years. In rural areas, it is 67.7 years.⁵

Maternal and infant mortality rates

The Infant Mortality Rate (IMR), which is widely accepted as a crude indicator of the overall health scenario of a country or a region, is defined as the infant deaths (less than one year) per thousand live births in a given time period and for a given region. Table 4 shows the IMR and MMR of Madhya Pradesh and how it has improved over the period of time.

⁵ <https://pib.gov.in/PressReleasePage.aspx?PRID=1606209>

Table 4: Infant Mortality Rate and Maternal Mortality Rate

	2015-17	2016-18	2019
IMR Madhya Pradesh	47 ⁶	48 ⁷	46 ⁸
	2015-17	2016-18	2017-19
MMR Madhya Pradesh ⁹	188	173	163

In the study area, the data on the number of infant and maternal deaths in the gram panchayat villages over the period of one year was recorded from the register of Anganwadi workers. Maternal deaths and Infant deaths are given in table.

Table 5: Number of Infant and Maternal Deaths in the survey area

Gram Panchayat	Maternal Deaths (in Numbers)	Infant Deaths (In Numbers)
Selda / Balabad	0	3
Dalchi	0	0

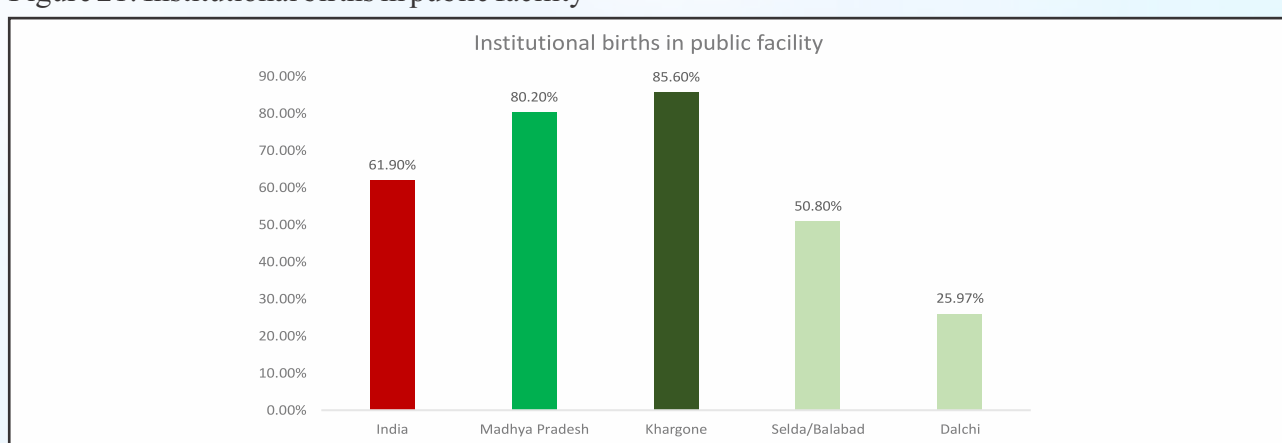
(Source: IICA Survey, 2022)

Institutional births in public facility (%)

Out of the total respondents of the study spread across Selda/Balabad and Dalchi, 5.71% of the respondents shared that their youngest child was born in private hospital, 37.96% shared that they opted for institutional birth in a public facility (government hospital), 28.4% respondents delivered their child at home. Out of those who delivered at home, 88.6% of the women were assisted by a health worker. The question did not apply to 13.89% of the respondents because their youngest child was too old for the purpose of the survey. Further, 14.04% of the respondents did not choose to answer the question.

With respect to institutional births in public facility i.e. government/district hospital, it was found that in Selda/Balabad, 50.80% of the surveyed households opted for institutional birth in public facility while in Dalchi, only 25.97% of the surveyed households opted for the same. As per the National Family Health Survey (NFHS-5) report 2019-2021, India's Institutional delivery in public health facilities is 61.9% while for Madhya Pradesh, it is 80.2%¹⁰. Further, the percentage of institutional delivery in Khargone district is 85.6% as per the NFHS-5 report for Madhya Pradesh¹¹. Therefore, it can be concluded that both Selda/Balabad and Dalchi lag behind the National, State and District benchmark for institutional delivery in a public health facility.

Figure 21: Institutional births in public facility



(Source: IICA Survey, 2022)

⁶ <https://hmis.nhp.gov.in/#/>

⁷ <https://hmis.nhp.gov.in/#/>

⁸ <https://hmis.nhp.gov.in/#/>

⁹ <https://censusindia.gov.in/nada/index.php/catalog/40525>

¹⁰ https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf

¹¹ http://rchiips.org/nfhs/NFHS-5Reports/Madhya_pradesh.pdf

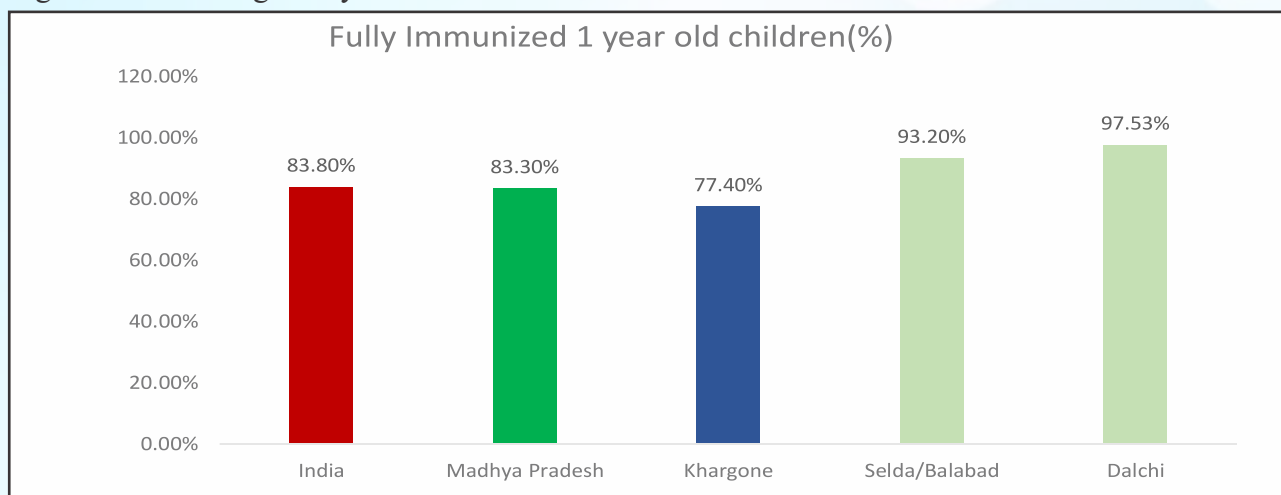


Percentage of 1 year old children immunized

Millions of lives are saved annually as a result of vaccination, which is a success story in global health and development. In order to build protection against disease, vaccines work with one's body's natural defences to protect against diseases.

Figure below depicts the percentage of one-year-old children (12-23 months) who are immunized. It is seen that Dalchi gram panchayat has more immunized children (97.53%) when compared to Selda/Balabad gram panchayat (93.2%). It is also quite evident that the percentage of immunized one-year-old children is more in the study gram panchayat villages than in the district (77.4%)¹², state (83.3%)¹³, and national level(83.8%) as per the NFHS-5 report.

Figure 22: Percentage of 1 year old children immunization status

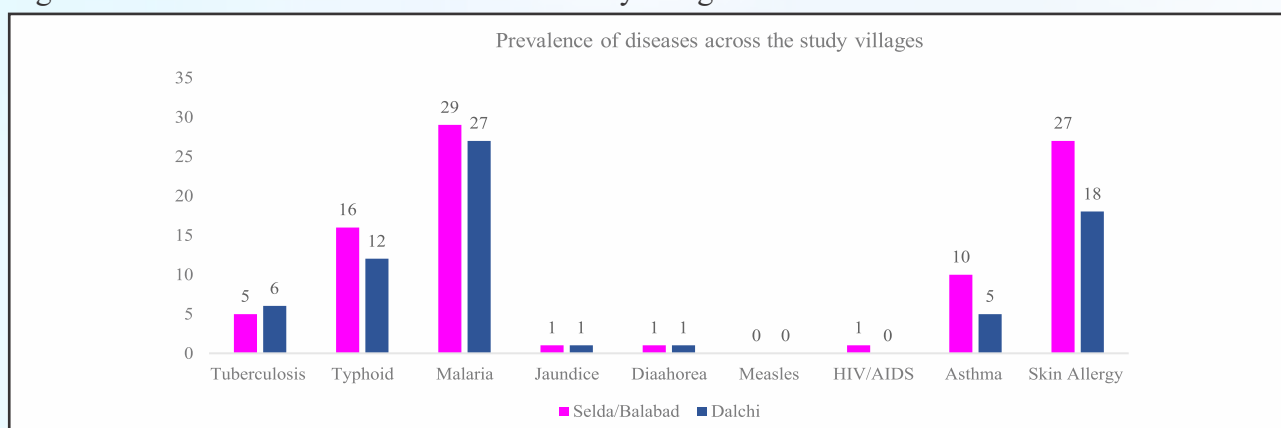


(Source: IICA Survey, 2022)

Prevalence of diseases

The figure below shows the prevalence of diseases across the study gram panchayat. The majority of the respondents (56) revealed that people suffer from malaria, while 28 respondents revealed that people suffer from Typhoid, 15 respondents revealed that people suffer from Asthma and 11 respondents revealed that people suffer from Tuberculosis.

Figure 23: Prevalence of diseases across the study villages



(Source: IICA Survey, 2022)

Incidence of anaemia cases

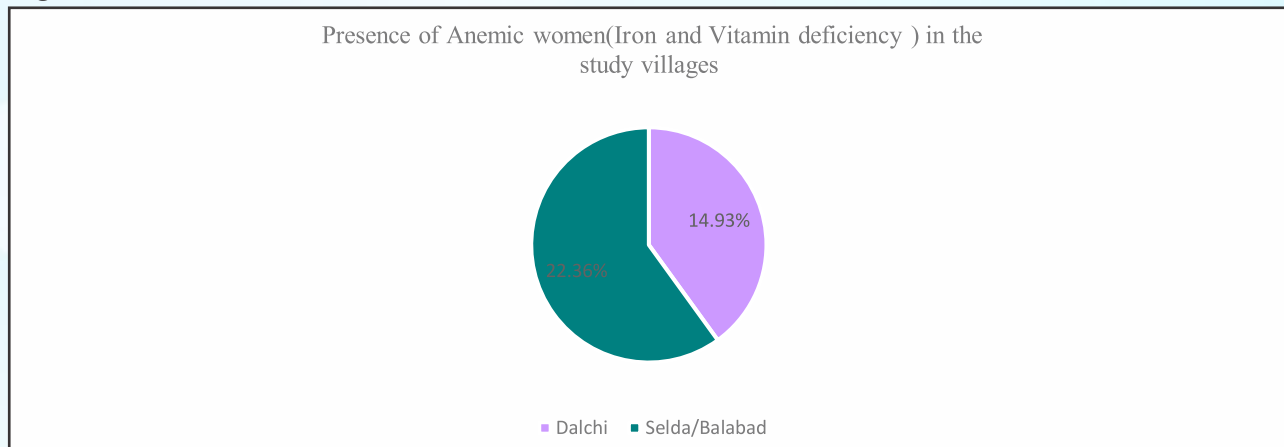
When there are not enough healthy red blood cells to deliver oxygen to ones' body organs, anaemia develops. As a result, a person experiences symptom of fatigue or weakness as well as a cold. Figure below depicts presence of anaemic women in the study gram panchayat villages. According to the Fifth National Family Health Survey (NFHS-5), At an all India level, 57% of all women aged between 15-49

¹² http://rchiips.org/nfhs/NFHS-5Reports/Madhya_pradesh.pdf

¹³ https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf

years are found to be anaemic while in the rural areas of India, 58.5% women are found to be anaemic¹⁴ It is reported that anaemic cases in Dalchi gram Panchayat is higher (14.93%) when compared to the anaemic cases in Selda/Balabad gram panchayat (22.36%).

Figure 24: Presence of Anaemic women



(Source: IICA Survey, 2022)

3.6 QUALITY OF LIFE

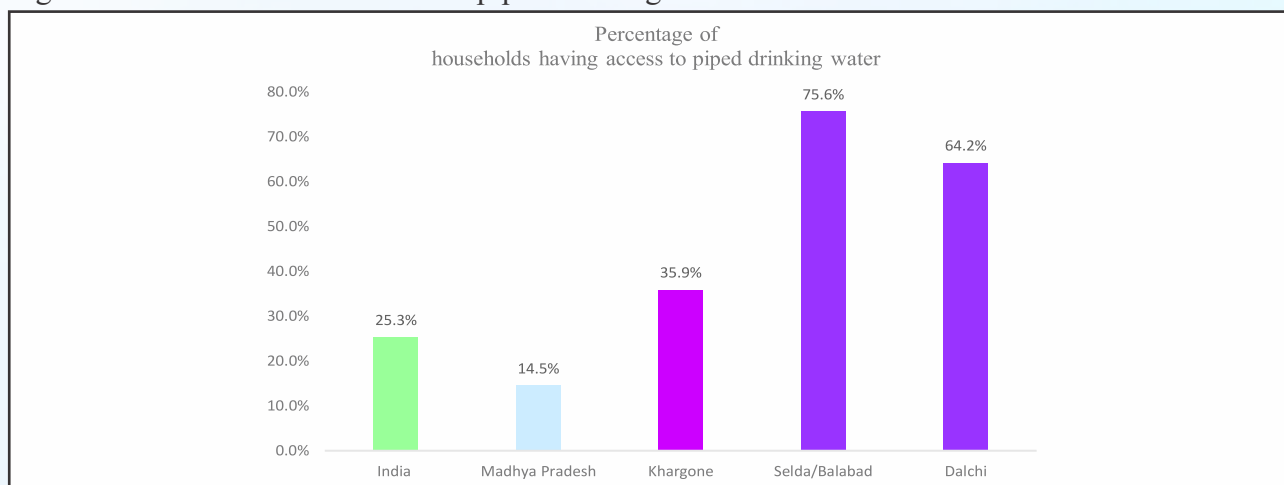
To assess the quality of life of the people in the study villages, indicators such as households having access to piped water, type of house, access to domestic electricity, and access to toilets are taken into consideration. These indicators are mapped against the national, state and district data from secondary sources like government databases and websites and village data as collected through household survey.

3.6.1 Households with piped drinking water

Around 25.3% households in India have piped drinking water connections. The percentage of households receiving piped drinking water directly at home is 14.5% in the state of Madhya Pradesh¹⁵.

The IICA survey found that the percentage of households covered with piped drinking water in Selda/Balabad (75.6%) and Dalchi (64.2%) are higher when compared to the district (35.9%), state (14.5%) and national bench mark (25.3%)

Figure 25: Households with access to piped drinking water



(Source: IICA survey, 2022)

Source of water

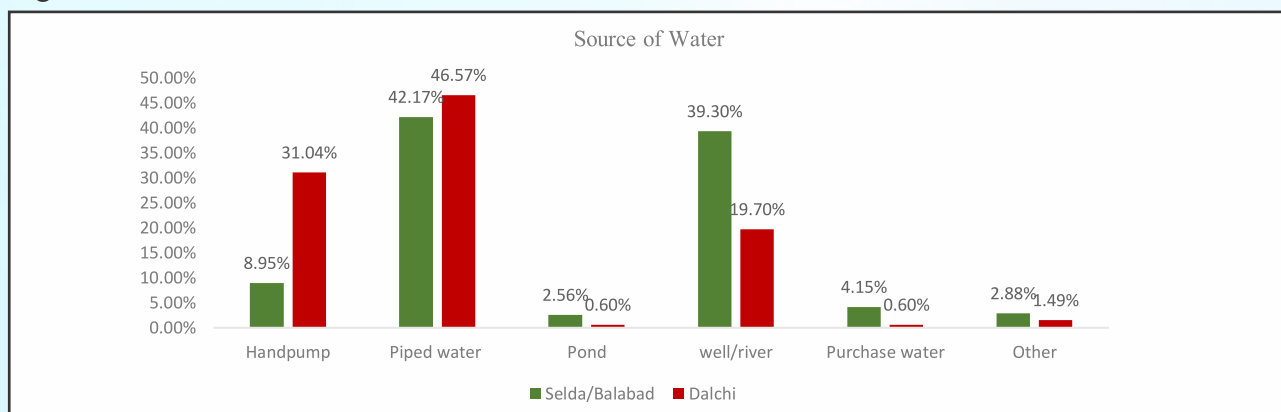
The major source of water for people in the area is piped water followed by hand pump, well/river in the study gram panchayat.

¹⁴ https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf

¹⁵ https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf



Figure 26: Source of Water



(Source: IICA survey, 2022)

Comparing the water supply facilities in Selda/Balabad and Dalchias per IICA Survey, 2022 with the baseline data in 2011 (as per the socio-economic study for KgSTPP), it was found that the water supply has significantly improved in the project affected villages. In 2011, the major source of water supply used to be wells and tube wells in the PAVs wherein people had to travel 350 m to fetch drinking water from the public tube wells. To make matter worse, only 40% of the public tube wells/handpumps were functional and maintained. Also, the inadequate depth of few tube wells made them non-functional especially during summers.

In 2022, a significant percentage of households in Selda/Balabad (75.6%) and Dalchi (64.2%) have access to piped drinking water, as also mentioned in the findings above. It is especially a significant improvement when compared to the socio-economic study for KgSTPP, 2011. This is because none of the houses in the PAVs in 2011 had their source of drinking water within their house itself. Additionally, the source of water also includes handpump, well/river, pond and purchased water.

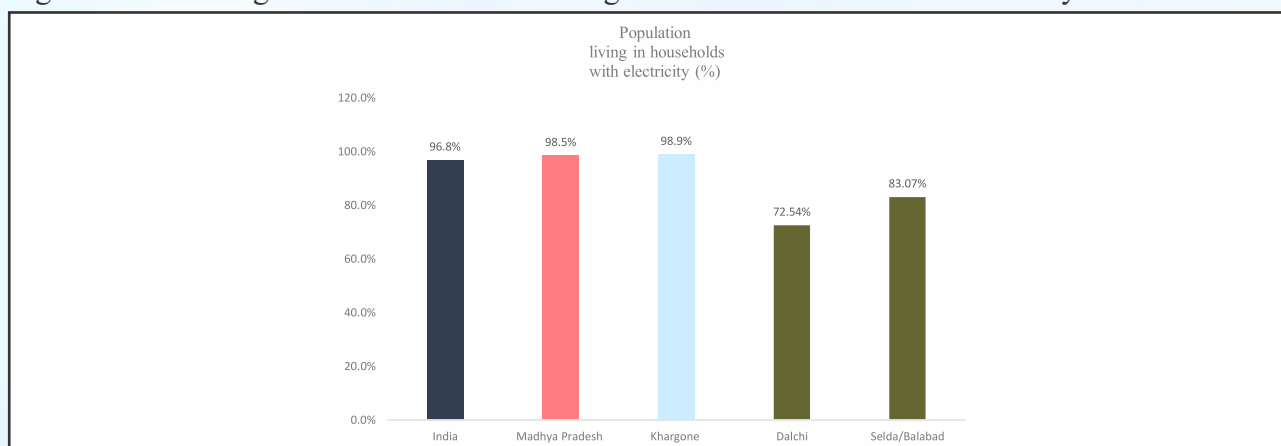
3.6.2 Households with access to domestic electricity

In terms of rural electrification in India (2018), about 88.2 % of households had electricity for domestic use. The percentage of electrified households in Madhya Pradesh is 98.5 % (as per NFHS 5 2019-21)

The socio-economic study for KgSTPP, 2011 suggests that while most of the PAVs had electricity facility, there were some hamlets that did not. However, the study does not mention the name of these hamlets. At the same time, the study mentions that all the PAVs have domestic electricity connections.

The data from IICA survey suggests that overall 83.07% of the households in Selda/Balabad and 72.54% of the households in the Dalchi gram panchayat had access to electricity. It is quite evident that the households with electricity connections in both the gram panchayat are lower than the national (96.8%), state (98.5 %) and district bench mark (98.9%).

Figure 27: Percentage of households in the Villages with access to domestic electricity

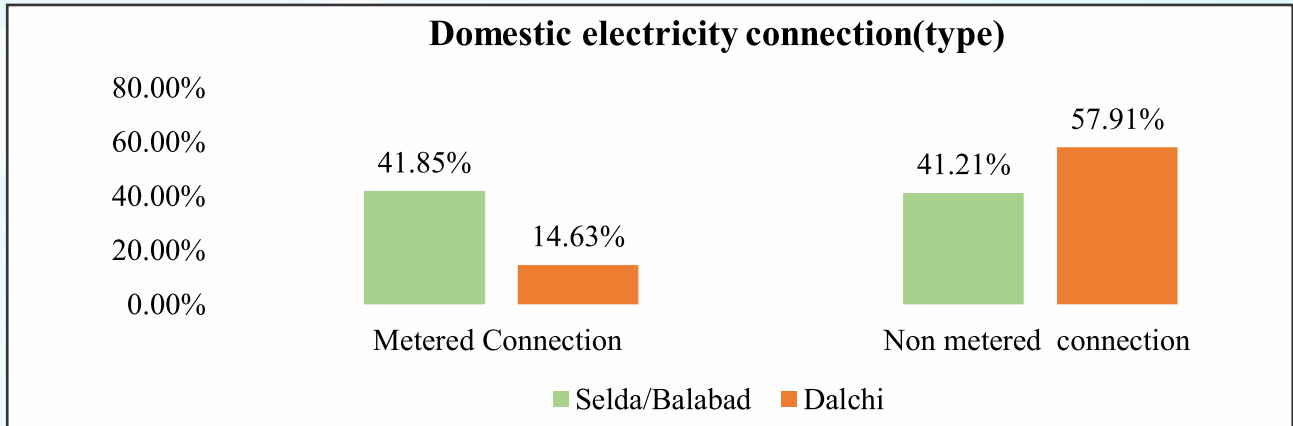


(Source: IICA Survey, 2022)

Electricity connection (type) in the households

Figure below depicts the type of electricity connections in the households. 41.85% of the surveyed households in Selda/Balabad and 14.63% of the surveyed households in Dalchi had metered electricity connections. It is also noted that Dalchi gram panchayat has more non-metered connections than the Selda/Balabad gram panchayat

Figure 28: Domestic electricity connection (type)



(Source: IICA Survey, 2022)

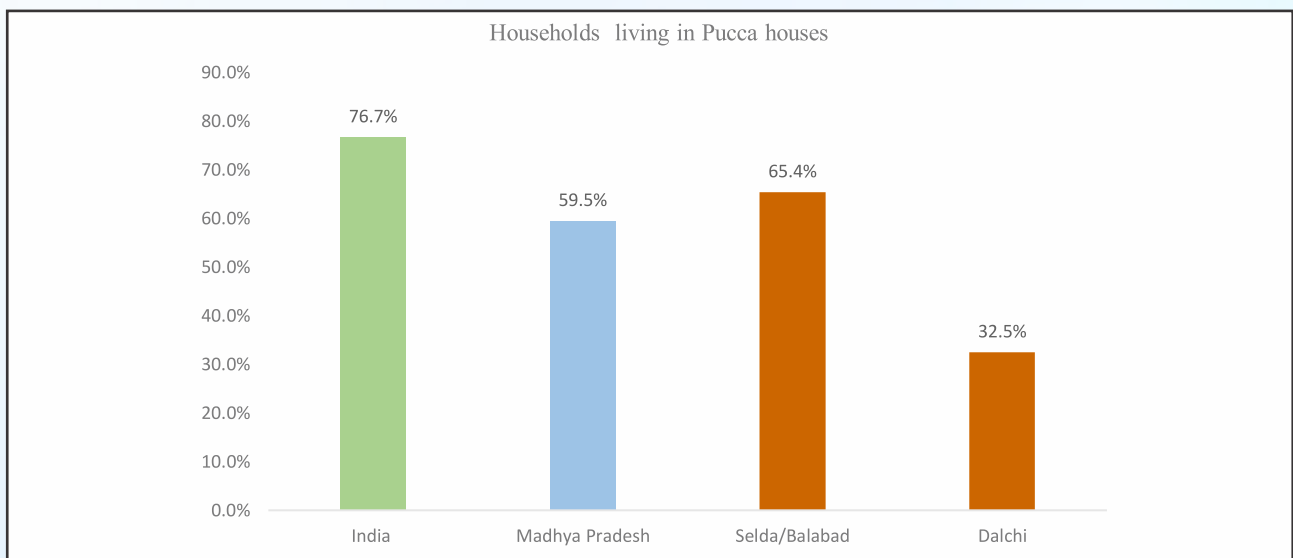
3.6.3 Population having pucca houses

Housing has a positive impact on the overall standard of living of rural people. In India, about 76.7 % households have the pucca structure, while in Madhya Pradesh 59.5 % of households have a pucca structure.

The socio-economic study for KgSTPP, 2011 found that the study area comprised only 17.06% houses having pucca structures. Rest of the houses (47.06%) had kutcha-pucca mixed structures while 35.88% houses had kutcha structures only. Compared to the baseline data, the IICA Survey, 2022 reveals that 65.5% respondents in Selda/Balabad and 32.5% respondents from Dalchi lived in Pucca houses. Therefore, it can be concluded that there has been significant improvement in the number of Pucca houses spread across Selda/Balabad and Dalchi.

Further, comparing the percentage of households having Pucca house structures with the National and State benchmark, while for Selda/Balabad, the percentage of households with pucca structure (65.5%) is higher than the state benchmark but lower than the National benchmark, for Dalchi, the percentage of households with Pucca structure (32.5%), is lower when compared to both the National and State benchmark.

Figure 29: Households living in Pucca houses



Source: IICA Survey, 2022)

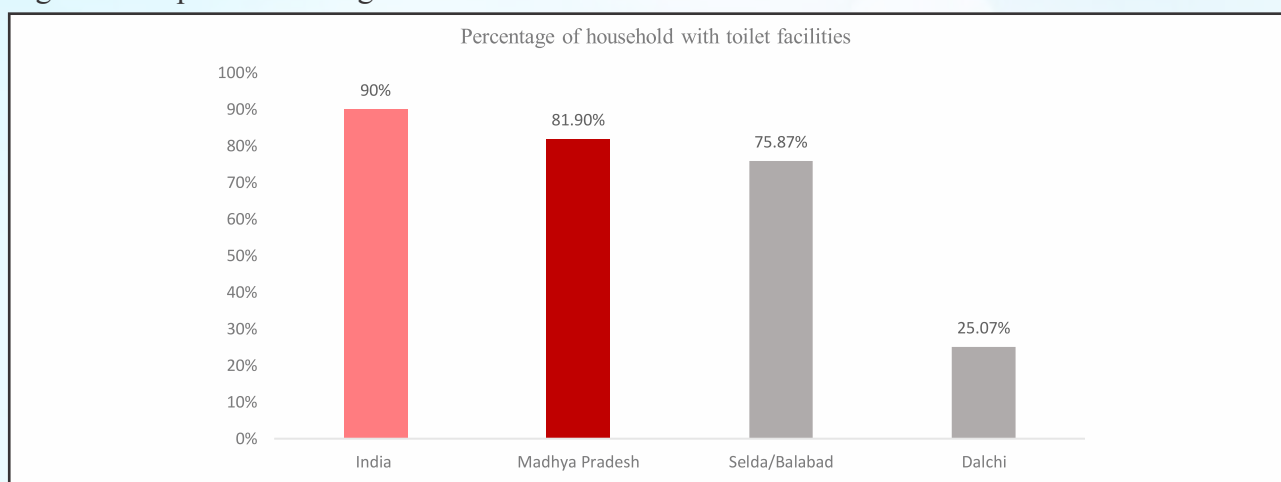


3.6.4 Population having toilet facility within the household

Every member of the home benefits from having a toilet, especially the women and girls. Men and women both experience the difficulty of visiting an open defecation location and the risk of catching infections, although these issues are more prevalent among women. The health issues are more severe for expecting mothers.

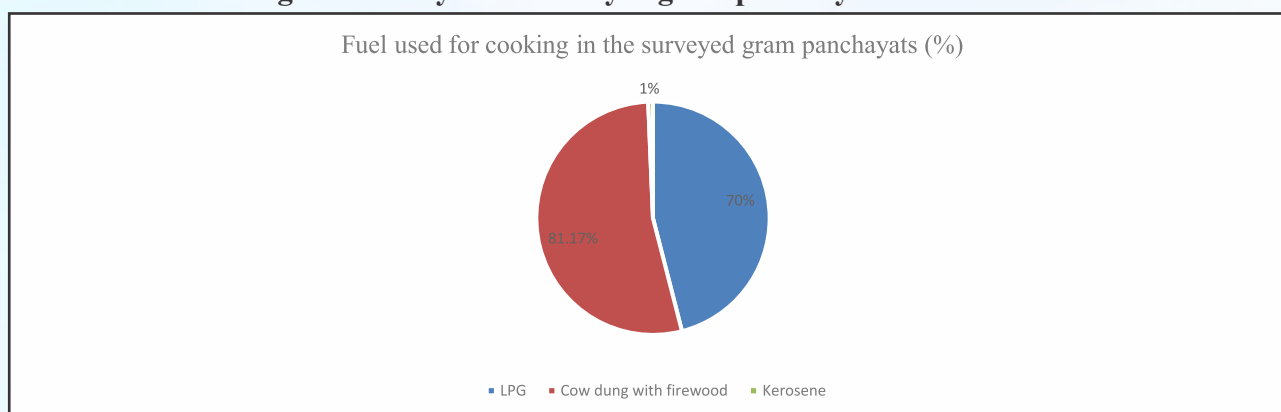
Figure 30 below depicts that the percentage of households with toilet facilities is low in both Selda/Balabad and Dalchi gram panchayats when compared to the national(90%) and state(81.9%) bench mark. Nevertheless, when compared with the baseline data, there has been a significant improvement in the percentage of households with toilet facility. As can be seen from the socio-economic study for KgSTPP, 2011, only 14.71% of the houses had separate and proper toilets. However, as per the IICA survey, 2022, 75.87 % of the surveyed households in Selda/Balabad and 25.07% of the surveyed households in Dalchi had toilet facilities. Furthermore, a significant difference between the percentage of households with toilet facilities in Dalchi and Selda/Balabad can be observed.

Figure 30: Population having Toilet facilities



(Source: IICA survey, 2022)

Fuel used for cooking in the study area/ surveyed gram panchayat



(Source: IICA survey, 2022)

As per the socio-economic study for KgSTPP, 2011, the majority of the PAPs in the study area used firewood as the main fuel for cooking. Additionally, the LPG, kerosene and electricity were also used as the supplementary cooking fuel.

The IICA Survey, 2022 shows that a majority of the surveyed households across Selda/Balabad and Dalchi Gram panchayat used Cow dung with firewood (81.17%) along with LPG (70%) as the main cooking fuel. Kerosene for cooking was used by only 1% of the surveyed households. Therefore, it can be said that while the LPG connections to the households have increased manifold in comparison to the 2011 baseline data, a majority of the households still rely on firewood as the main fuel for cooking.



4. KNOWLEDGE, ATTITUDE AND PRACTICES ANALYSIS (KAP)

4.1 LANGUAGE AND HABIT OF COMMUNICATION

The major language spoken by the locals in the region is Nimadi followed by Hindi. Nimadi speakers use Hindi mainly in education and for communication with outsiders. Nimadi is actually a form of the Malvi dialect of Rajasthani, but it has enough distinct characteristics of its own to be taken into account separately. A small portion of the population also speaks Adivasi, Banjara.

4.2 CULTURAL CHARACTERISTICS, TRADITIONS, VALUES, BELIEFS

Kanbai festival: The Kanbai Festival is celebrated by Nimadis people.

Navratri Festival: On this holiday, Durga, the goddess of might is worshipped.

Diwali: The Nimadi people celebrate Diwali with a tremendous deal of excitement. The celebration is marked for five days, with a great deal of excitement. On Dhanteras, a holiday honouring the goddess Dhanteras, people typically purchase new clothes, gold jewellery, metal utensils, and diyas for lighting up their homes.

Gangaur festival: The Gangaur festival is very significant for the Nimar citizens. Gauri, Lord Shiva's wife, is honoured during an annual festival that takes place in her honour. Visitors to the temple pay respect there. The Gangaur celebrations are a part of Rajasthani culture and tradition. Unmarried girls worship Gauri in order to make sure they find a nice and attractive spouse, while married women worship Gauri for blessing their spouse with long life. This event is among the major activities in the Nimad region.



5. AGRICULTURE DEVELOPMENT

Out of the total population surveyed, 63.9 per cent of respondents are engaged in agricultural activities.

Rainfall: The Khargone district in Madhya Pradesh has a hot summer and is generally dry, with the exception of the south-west monsoon season. There are four distinct seasons in a year. The hot season follows the cold season, which lasts from December to February. The south west monsoon season lasts from the middle of June to September. The post-monsoon or transitional period is formed by October and November.

835 mm of rain falls typically each year in the Khargone district. About 92.8% of the annual rainfall in the monsoon season is received at its highest during the June to September south-west monsoon period. Only 7.2% of the annual rainfall falls between the months of October and May. As a result, the only time surplus water is available for ground water recharge is during the south west monsoon season.

Agriculture: Since 63.9% population is engaged in agriculture in the study gram panchayat villages, they are engaged in rainfed- subsistence farming with traditional means. The people are either farming on their land or working as agricultural labourers in the villages. The major crops grown in the area are food grains, pulses, cash crops and oilseeds

Around 57.87% of the respondents spread across Selda/Balabad and Dalchi said that the major issue that they are facing is lack of water for irrigation for farming and are unable to access new techniques in farming.

Further, on an analysis of the baseline data (2011), as per the socio-economic study for KgSTPP, a significant part of the land in these PAVs were deprived of the irrigation facilities except during monsoon. Also, due to the unavailability of electricity, backwardness and poverty, very few tube wells were in use for the irrigation purpose. However, the IICA Survey, 2022 reveals that there has not been much improvement in the circumstances of people as more than half of the respondents of the study (57.87%) were unable to access the new farming techniques or have sufficient water for irrigation.

6. INFRASTRUCTURE AVAILABLE

Rural areas continue to face significant difficulties in providing dependable and efficient infrastructure. In order to better understand the need for school infrastructure, field research was done in each of the two gram panchayat villages. For the local population to meet their basic needs in these areas, infrastructure assets such as rural roads, tracks, bridges, irrigation schemes, water supplies, schools, health centres, and markets are required.

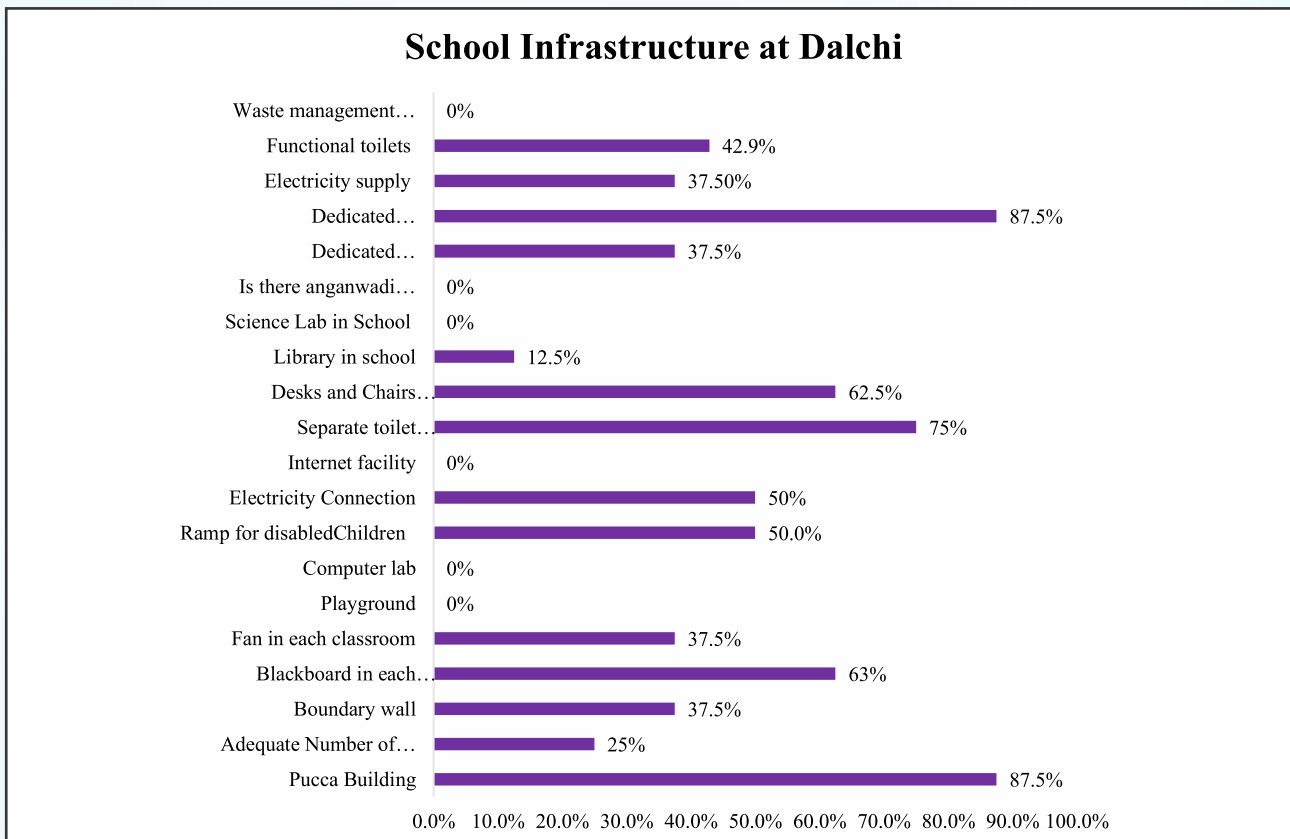
6.1 SCHOOL INFRASTRUCTURE

In survey villages of Khargone district, the public schooling system is functional, but the quality of education and school infrastructure still needs a lot of improvement as observed during the conversations with the respondents and key stakeholders in the area. To further understand the availability of basic facilities in schools, key informant interviews were conducted with school officials. The school infrastructure has been analysed separately for Dalchi and Selda gram panchayat.

Figure below shows that most of the surveyed schools in Dalchi have ramps for PWDs (50%) and 63% of the surveyed schools had an adequate number of blackboards. 37.5% of the surveyed schools had an adequate number of fans and 75% of the surveyed schools had a separate toilet for boys and girls. Additionally, important facilities like a library were found in 12.5% of the schools.

None of the surveyed schools in Dalchi had internet access, a computer lab, a science lab, and a playground.

Figure 31: School Infrastructure at Dalchi

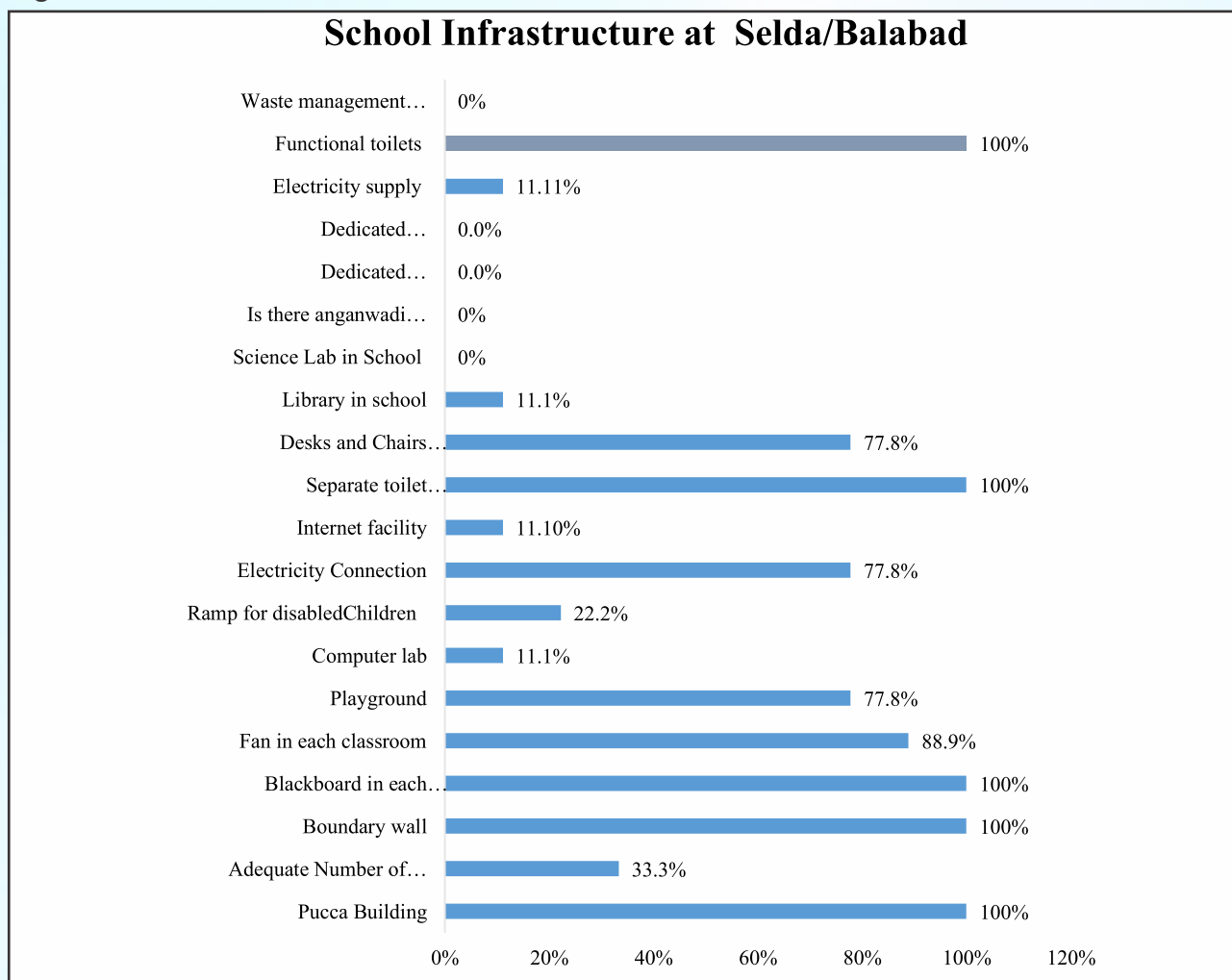


(Source: IICA Survey, 2022)

Figure below shows that some of the surveyed schools in Selda have ramp for PWDs (22.2%) All of the surveyed schools had an adequate number of blackboards and 77.8% of the surveyed schools had a playground. 88.9% of the surveyed schools had an adequate number of fans and all of the surveyed schools had a separate toilet for boys and girls. Additionally, important facilities like a library, playground, computer lab, and internet facilities were found only in 11.1%, 77.8%, 11.1%, and 11.1 percent of the surveyed schools respectively. None of the surveyed schools had a science lab.



Figure 32: School Infrastructure at Selda/Balabad



(Source: IICA Survey, 2022)

IICA's communication with NTPC Khargone officials revealed that a learning level improvement programme was developed by them for the schools. Further, NTPC Khargone also constructed/renovated the classrooms and the school buildings, in addition to providing the students with water facilities. Moreover, fans were provided by NTPC Khargone, L&T as well as the government. At the same time, the donors also want to contribute towards the development of a comfortable environment at school. Furthermore, as per NTPC Khargone, all the schools at Dalchi, Bedipura, Nurufaliya & Lalyachappad have separate toilets for girls and boys. While NTPC Khargone is concerned for the healthcare, sanitation facilities and hygiene level of the PAVs, they have not received any request from the people in the study area for the construction/renovation of toilets.

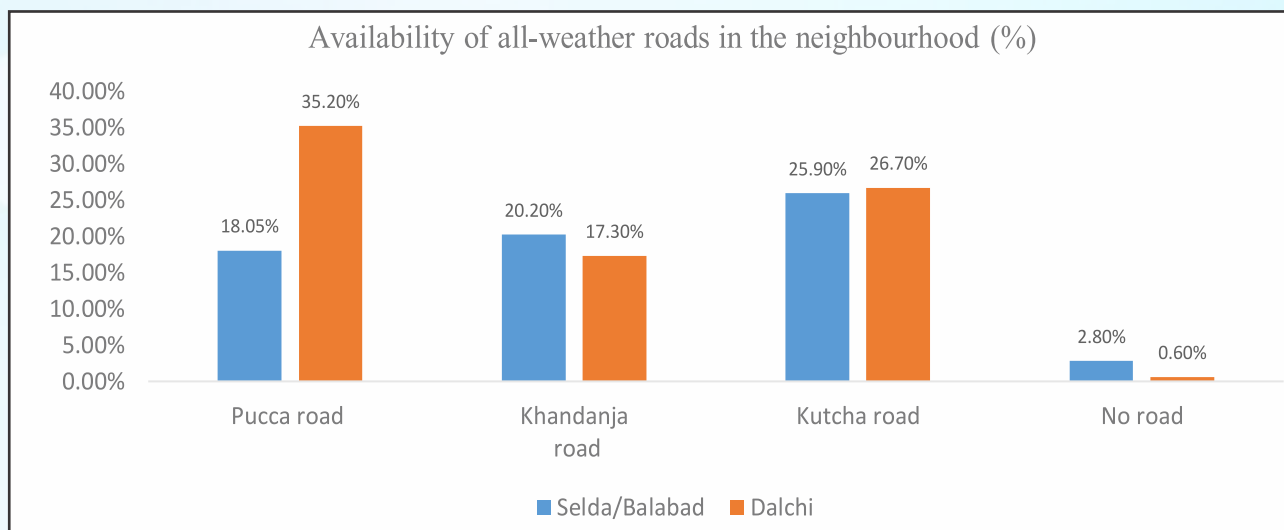
6.2 AVAILABILITY OF ALL-WEATHER ROADS

Rural living conditions are impacted by road connectivity in two ways. One benefit is that it gives local communities faster, more dependable access to goods, services, information, and social connections from the outside world. Two, connectivity makes it possible for communities to fully utilise the government services already in place that benefit rural areas. Additionally, because there is a relationship between rural connectivity and growth, employment, education, and healthcare, road connectivity projects have significant socio-economic effects on the lives of beneficiaries.

According to Mission Antyodaya dashboard (2019-20), the all-weather road coverage is 77 % in Madhya Pradesh and 74 % in Khargone. 35.2% of respondents in Dalchi gram panchayat villages confirmed the availability of pucca roads in their neighbourhood. Similarly, 18.05% of the respondents in of Selda/Balabad gram panchayat villages confirmed the availability of pucca roads in their neighbourhood.

20.20% of the respondents in Selda/Balabad gram panchayat and 17.3 % of the respondents in Dalchi gram panchayat confirmed the presence of Kharanja road in their neighbourhood. Similarly,25.90 % of the respondents in Selda/Balabad gram panchayat and 26.70 % of the respondents in Dalchi gram panchayat confirmed the presence of Kutcha Road in their neighbourhood.

Figure 33: Availability of all-weather roads in the neighbourhood (%)



(Source: IICA Survey, 2022)

As per the socio-economic study for KgSTPP, 2011, while the PAVs were accessible through all-weather roads and the fair weather roads, a significant variation in accessibility to these roads was found amongst the different hamlets/tollas of the PAVs. The report mentions that some hamlets were connected to all-weather roads and few hamlets were connected to fair weather roads which were not in a good condition. The report also mentions that there were 2 concrete roads of 200 m length at Selda/Balabad and 60.6 m length at Dalchi, and that the people did not have any metalled road. Moreover, there were 20 Kutcha roads at Selda/Balabad (2500 m in length) and 10 Kutcha roads at Dalchi (909.1m length).

Therefore, when compared with the findings of IICA survey, 2022 (Figure 33), it can be said that while the percentage of people who have access to pucca/cemented/concrete roads have increased in the past 10 years, there is scope of much more improvement.

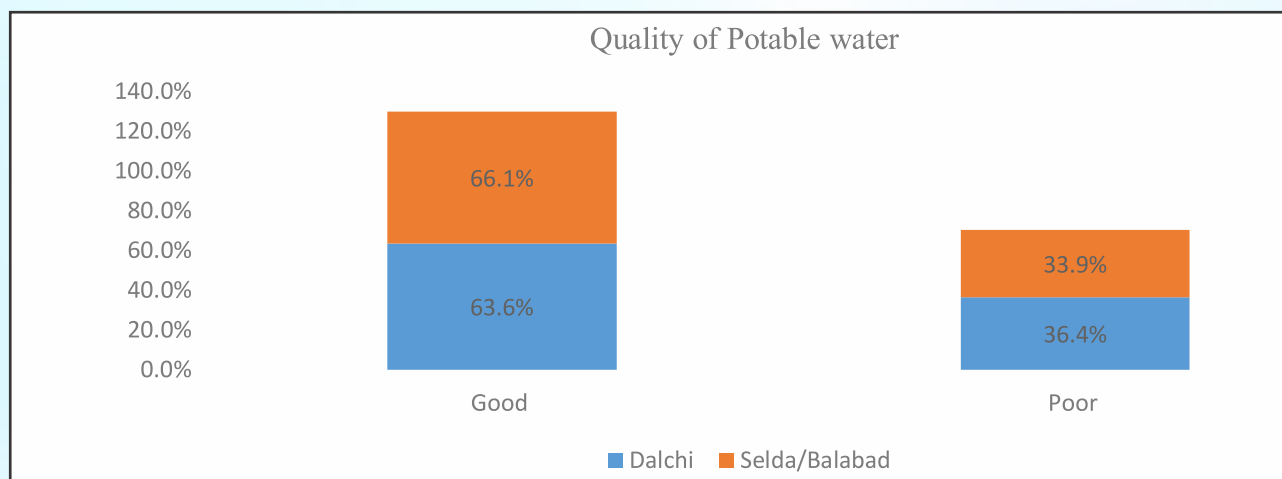
Furthermore, the communication with the NTPC Khargone officials revealed they have constructed 1 kilometre long Cement Concrete (CC) road in Dalchi, along with 2.5 Km road on deposit work through MP Rural Road Development Authority (MPRRDA), Gram Panchayat and other contractors. NTPC Khargone also informed that soon they would be awarding the contract for construction of 1 Kilometre road to Hariom construction. Additionally, the surveyed area was not well connected to Bediya prior to 2013. It was only after NTPC Khargone's intervention that accessibility of the people to Bediya improved.

6.3 QUALITY OF POTABLE WATER

Water needs to be pure and free of contaminants like disease, metals, and human and animal faces because it passes through our organs and cells. Drinking unclean or unfiltered water that might be contaminated can make one sick. Diarrhoea is among the most typical negative effects of ingesting contaminated water. If improperly addressed, this side effect alone has the potential to be fatal. Figure below depicts that 63.6% of the respondents revealed that water available for drinking in Dalchi gram panchayat village is of good quality. Similarly, 66.1% of the respondents revealed that water available for drinking in Selda/Balabad gram panchayat village is of good quality.



Figure 34: Quality of potable water(Source: IICA Survey, 2022)

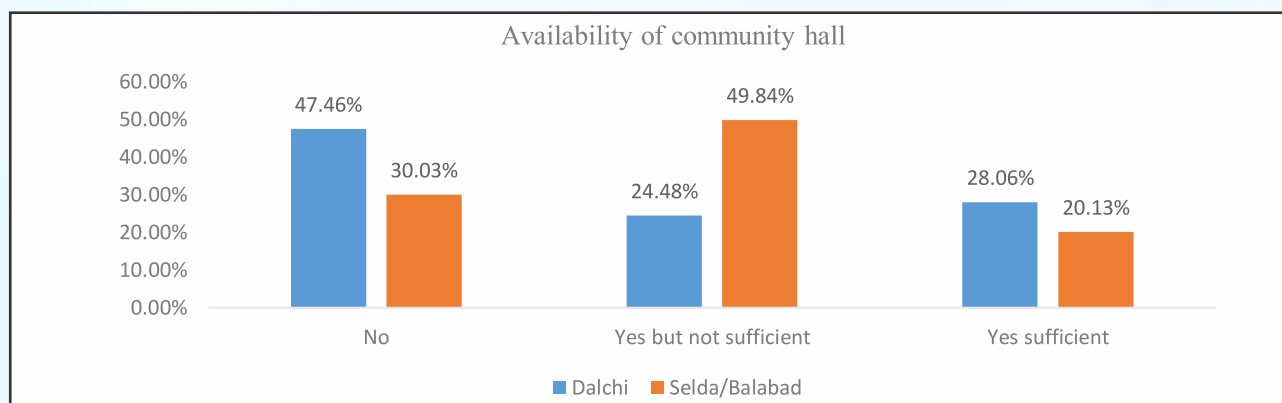


(Source: IICA Survey, 2022)

6.4 AVAILABILITY OF COMMUNITY HALL

Figure below explains the availability of community hall in the study villages. 30.03% respondents from Selda/Balabad gram panchayat and 47.46 % respondents from Dalchi gram panchayat denied any availability of a community hall in the locality. It is also reported that 20.13 %of respondents from Selda/Balabad gram panchayat and 28.06% from Dalchi gram panchayat were satisfied with the availability of community hall in their neighbourhood.

Figure 35: Availability of community hall




(Source: IICA Survey, 2022)

The communication with NTPC Khargone officials revealed that the community halls were constructed by them in both the Selda/Balabad and Dalchi Gram Panchayat. Additionally, NTPC Khargone renovated a community hall especially for the SC community in the study area. Apart from the community halls, NTPC Khargone made other infrastructural interventions like the construction and renovation of schools, classroom buildings, sanitation and drainage facilities as well as in providing healthcare to the people in the surveyed area. Thus, it can be said that the surveyed gram panchayat have developed compared to their situation in 2013.

Possession of assets

As per the Socio-economic study for KgSTPP, 2011, material assets such as bicycle, motorbike, four-wheeler happened to be the most common form of assets possessed by the PAPs. The total number of transport related material assets happened to be 164. When compared with the IICA Survey, 2022, it was found that out of the total number of surveyed households spread across Selda/Balabad and Dalchi, 35 households had four- wheeler, 64 households had bicycle, 396 households had Motorbike, and 3 households had tractor.



Furthermore, the communication related material assets including the telephone and mobile phone happened to be 163 as per the baseline data, 2011. When compared with the IICA Survey, 2022, it was found that out of the total households surveyed across Selda/Balabad and Dalchi, 549 households had a mobile phone. Moreover, the modern household related gadgets such as cooking gas, refrigerator and cooler, as well as entertainment related assets such as the TV, Radio etc. as found during the socio-economic study for KgSTPP in 2011 was very low due to the poor economic condition of the people. When compared with the IICA Survey, 2011, it was found that across all the surveyed households in Selda/Balabad and Dalchi, 439 respondents confirmed having access to cooking gas, 63 respondents had refrigerator in their household, cooler was found in 3 households, and 336 households had Television. Additionally, computer/laptop was possessed by 6 respondents, and gristmill or Atta Chakki by 2 respondents. However, there were 60 respondents who said that they did not have any of the above mentioned assets.

Based on the analysis above, it can therefore be concluded that as compared to 2011, the living conditions of the majority of the surveyed households in 2022 have improved significantly in context of the material assets possessed by them.

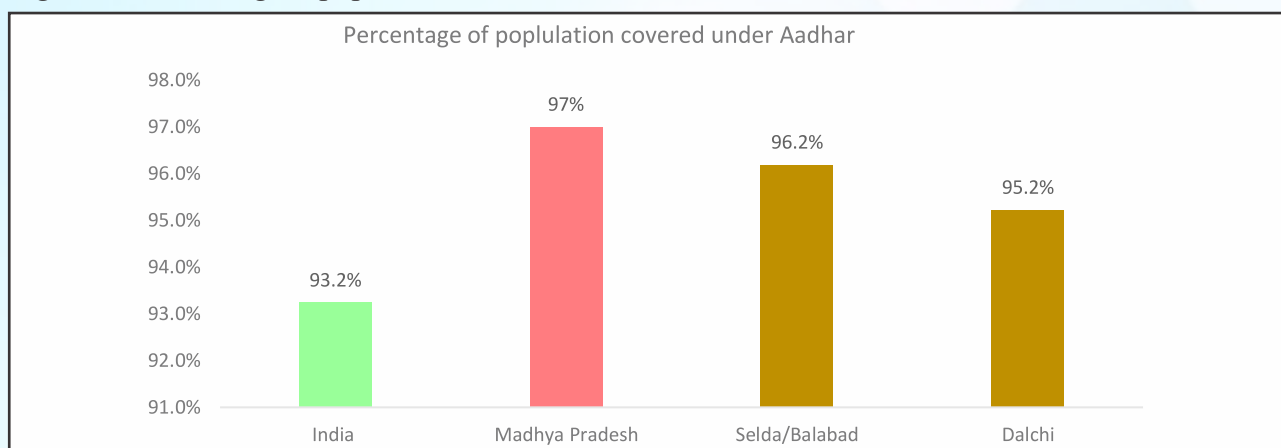


7. OTHER

7.1 POPULATION COVERED UNDER AADHAR

The graph below depicts the percentage of respondents covered under Aadhar. It is reported that most of the respondents in the study gram panchayat are covered under Aadhar scheme. The maximum percentage of households with all members covered under Aadhar are from Selda/Balabad (96.2%) which is higher than the National level (93.2%) but less than the state level (97%)

Figure 36: Percentage of population covered under Aadhar

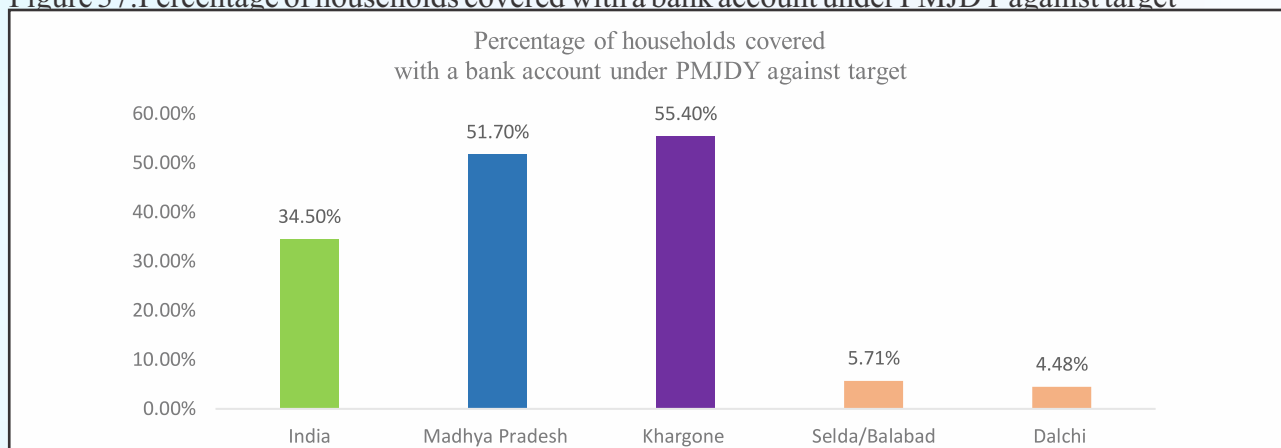


(Source: IICA Survey, 2022)

7.2 PERCENTAGE OF HOUSEHOLDS COVERED WITH A BANK ACCOUNT UNDER PMJDY TARGET

It is reported that the percentage of households covered with a bank account under PMJDY is low for Selda/Balabad gram panchayat village (5.71%) and Dalchi gram panchayat (4.48%). When compared to the district (55.40%), state (51.70%) and national benchmark (34.50%), it seems that the benefits of banking system has still many more mile to cover in rural India.

Figure 37: Percentage of households covered with a bank account under PMJDY against target

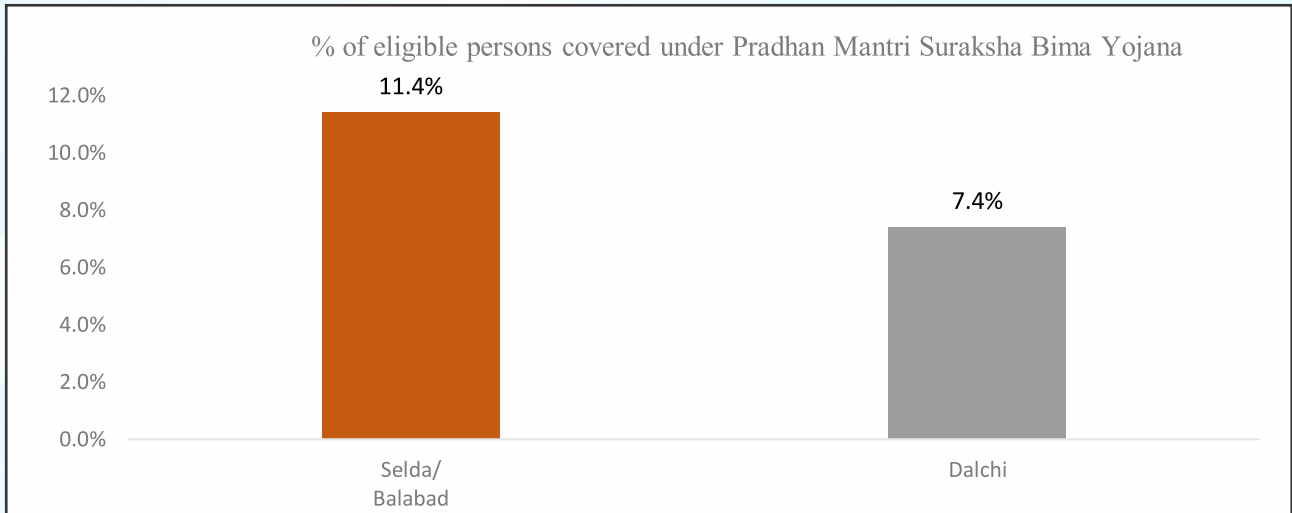


(Source: IICA Survey, 2022)

7.3 PERCENTAGE OF ELIGIBLE PERSONS COVERED UNDER PMSBY

The percentage of eligible persons covered under Pradhan Mantri Suraksha Bima Yojana is higher for Selda/Balabad gram Panchayat (11.4%) than in Dalchi gram panchayat (7.4%). Lack of information about the prevailing schemes might be the reason for such less coverage of respondents.

Figure 38: Percentage of eligible persons covered under Pradhan Mantri Suraksha Bima Yojana

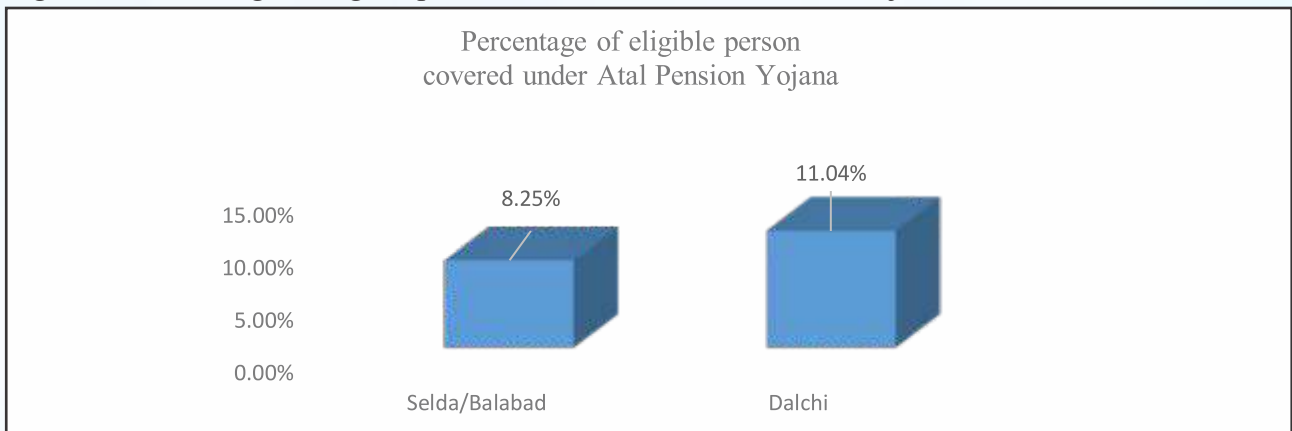


(Source: IICA Survey, 2022)

7.4 PERCENTAGE OF ELIGIBLE PERSON COVERED UNDER ATAL PENSION YOJANA

The percentage of eligible persons covered under Atal Pension Yojana is higher for Dalchi gram Panchayat (11.04%) than in Selda/Balabad gram panchayat (8.25%). Lack of information about the prevailing schemes might be the reason for such low coverage.

Figure 39: Percentage of eligible person covered under Atal Pension Yojana



(Source: IICA Survey, 2022)



8. KEY FINDINGS- SOCIAL IMPACT EVALUATION

8.1 IMPACT OF INTERVENTIONS IN EDUCATION

With an aim to promote education, NTPC Khargone undertook the following activities in the Project Affected Gram Panchayats namely Selda/Balabad and Dalchi.

- Construction of school building and boundary walls
- Distribution of uniforms, school bags, and stationary
- Renovation of classrooms
- Merit scholarships to students
- EVOICE- R& R department of NTPC Khargone in association with Evoice and BBPS provided coaching for 10th class students
- Girls merit award and Utkarsh scholarship to students
- 42 girls are enrolled for one-month residential Girl Empowerment Mission (GEM) workshop and 10 Girls out of these 42 were selected for BBPS which is an English medium school. Their financial, academic and medical expenditure have been adopted by NTPC Khargone.
- Elocution, Drawing, Sports Cultural and other activities are organized by NTPC Khargone.

A total of 17 schools including 10 primary schools, 5 secondary schools and 2 higher secondary schools were included in the study. All the schools were co-educational, Hindi medium and government schools. The teachers, principals, non-teaching staff, students and the villagers were interviewed to understand the impact of the educational interventions of NTPC Khargone in schools.

Image 2: School buildings at Selda and Dalchi



Source: IICA Survey, 2022

Image 3: Classrooms at schools in Selda and Dalchi



Source: IICA Survey, 2022

Image 4: Girls' toilets at schools in Selda and Dalchi



Source: IICA Survey, 2022

Image 5: Installation of Smart TV at a high school in Selda for smart classes and EVOICE initiative by NTPC Khargone



Source: IICA Survey, 2022



Image 6: Scholarships, Coaching and Uniforms to school students in Selda and Dalchi



Source: NTPC Khargone

Impact: Out of all the surveyed schools spread across Selda/Balabad and Dalchi, the IICA survey, 2022 found that there was one primary school at Dalchi which did not have a pucca building. The middle school at Dalchi comprises students belonging to 1st upto 8th standard. The middle school at Dalchi required an extra classroom. A new school was therefore approved by NTPC Khargone. However, till the time the NOC for the same is awaited, the classes for the middle school are conducted at the community hall constructed by NTPC Khargone. Further, all the surveyed schools had boundary walls except five schools at Dalchi. Moreover, there were three schools at Dalchi that did not have a blackboard. Also, all the schools had a functional fan except six schools, one at Selda and five at Dalchi. However, all the schools had provision of mid-day meals. All the schools had toilets except one at Dalchi, however, there was one school which did not have a separate toilet for girls. Moreover, all the surveyed schools except three schools at Dalchi and two schools at Selda had adequate number of desks, chairs and benches. Further, there were six schools, four at Dalchi and two at Selda that did not have an electricity supply. None of the schools had a safe waste disposal facility.

Overall, the teachers and principals of 12 out of 17 surveyed schools shared that NTPC Khargone made educational interventions which improved the school and education system. According to the respondents, NTPC Khargone renovated the school building, constructed the boundary wall, provided benches, almirahs, furniture, constructed toilet and contributed towards its maintenance, provided study kit for students, fans, water cooler and purifier. Moreover, school bags and uniform distribution was undertaken by NTPC Khargone in the project villages and merit scholarships (Utkarsh) was provided to the school students which created a positive impact on the lives of students. The survey team found the presence of Smart TVs in school installed by NTPC Khargone where classes through EVOICE platform were conducted for the students.

Relevance: The construction and renovation of the school infrastructure and provision of educational resources such as books and uniforms is highly relevant in the project affected villages. This is because it motivates the children to come to school as well as provides an opportunity and learning space for the educational development of the children. Further, the merit scholarship or NTPC Utkarsh is highly relevant as it encourages and motivates children and youth from the neighbourhood villages of NTPC Stations for higher studies. Since FY 2016-17, the Utkarsh scheme is aimed at benefitting about 7300 students every year from neighbourhood communities pursuing X, XII, ITI, B.E / B.Tech and MBBS studies.

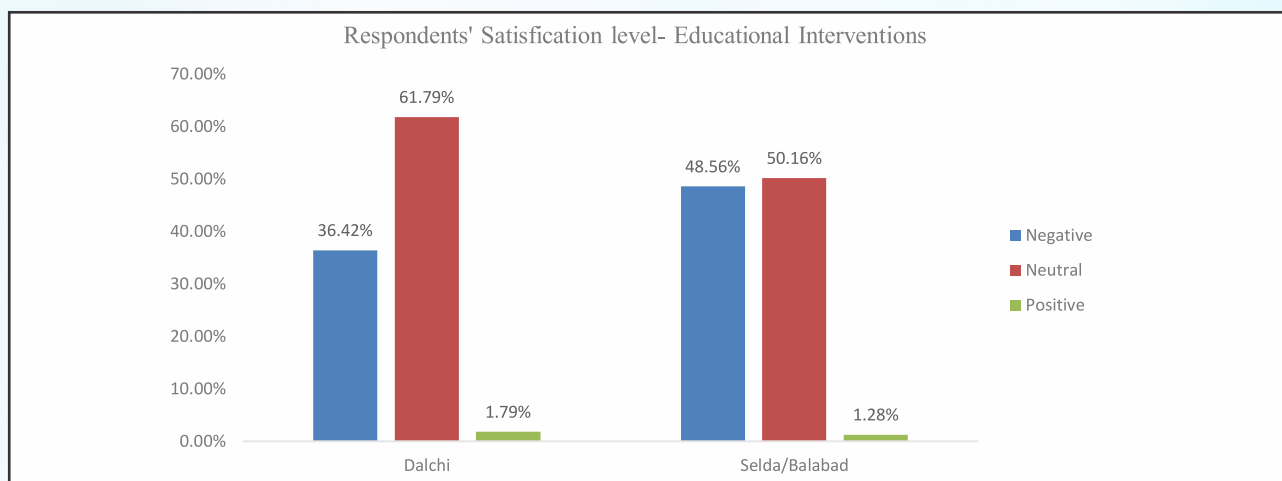
Effectiveness: The effectiveness of the community development programs/interventions relates to the 'level' by which the program activities produce the desired effect. 95% respondents from Dalchi and

92% respondents from Selda felt that no educational interventions were made by NTPC Khargone. However, 5% respondents from Dalchi and 6% respondents from Selda shared that NTPC Khargone made educational interventions such as the construction of boundary walls, repair of the school building, distribution of pencils, notebooks once in a year, provided books, furniture, and LCD TV. Around 2% respondents from Selda said that they did not have an idea about the educational contributions of NTPC Khargone for the community.

Sustainability: The sustainability of infrastructural assets created by NTPC Khargone requires maintenance. Therefore, for ensuring a long term sustainability of the infrastructure, NTPC Khargone may enter into an agreement with the beneficiaries regarding the maintenance of the assets, before the implementation of any project. With respect to other educational interventions like the provision of study material and uniforms, NTPC Khargone requires to provide financial support to the students since they come from lower socio- economic strata of the society.

The following figure represents the perception and satisfaction level of the respondents towards the educational interventions made by NTPC Khargone in Selda/Balabad and Dalchi along with their associated hamlets.

Figure 40: Perception and satisfaction level of the respondents towards the educational interventions



Source: IICA Survey, 2022

8.2 IMPACT OF INTERVENTIONS IN HEALTH

There were no medical facilities in the surveyed area in 2011 as per the Socio-Economic Study for KgSTPP. The baseline survey report mentions that there were no health sub-centres in the Project Affected Villages (PAVs). People from Selda/Balabad had to travel 10Km to reach the Primary Health Centre at Bedia. People from Dalchi had to travel 15km to reach the primary health centre at Pipalgone. Furthermore, even for accessing the health sub-centre, the people had to travel 17 to 27kms to reach Bedia or Sanawad. Also, for reaching the nearest diagnostic centre located at Bedia, the people had to travel 10-17Kms. The poor condition of the roads especially during rainy season further decreased the accessibility of the patients to receive medical services. As mentioned in the baseline report, the non-availability of the medical staff and doctors as well as the high cost of transportation to the health centre added to the woes of the people in the PAVs.

The Socio-Economic Study for KgSTPP, 2011 further mentions that the general health of the PAVs was poor due to malnutrition. The women and children suffered from poor health because of the reproductive cycle. Further, the hygiene related conditions of the PAVs was also poor as there were no garbage and/or waste water disposal system. Most of the houses except the pucca ones did not have toilet facilities and separate bathrooms.

Given the grave situation of health and hygiene in the PAVs in 2011, NTPC Khargone undertook the following activities with an aim to promote the healthcare situation in the Project Affected Gram Panchayats namely Selda/Balabad and Dalchi

- Construction of Anganwadi centres
- Mobile Medical Unit
- Maternal and Child Health Care: In FY 2022-23, 303 women were given nutritional supplements under this program by NTPC Khargone.
- Menstrual Hygiene talks for girls students
- Health awareness sessions
- Medical camps
- Child health and Family planning incentives

The AWWs, ANMs, ASHAs, doctors, adolescent girls, men and women were interviewed to understand the impact of NTPC Khargone's health interventions in Selda and Dalchi. The health facilities available at Selda/Balabad and Dalchi include Anganwadi Centres and Private Clinics. An NTPC hospital is also available to the people in the surveyed area. Moreover, the majority of the respondents (78.24%) said that they had to travel more than 5km for reaching the Primary Health Centre/District hospital. Therefore, to cater to the medical needs of the villagers, NTPC Khargone operates Mobile Medical Units in its Project Affected Villages. Therefore, the impact of health Interventions by NTPC Khargone have been mainly studied through Anganwadi centres and Mobile Medical Units.

Anganwadi Centre

All the health workers said that the condition of Anganwadi centre in the village was very bad although a majority of them appreciated the quality of nutrition supply. According to the health workers, all eligible children of the village were immunized and none of the mothers died at the time of child birth. However, there were three infant deaths in the past one year. The facilities provided to the Anganwadi Centres included nutrition and health education to the parents, immunization of children, early childhood care, pre-school education, pregnant women's health check-up and counselling, and screening/identification of high risk pregnancies, supply of Calcium, Iron and Deworming tablets. Mamta Divas or Village Health and Nutrition Days are also organized at the Anganwadis.

The health workers said that not much intervention has been done by NTPC Khargone for the welfare of women, adolescent girls and children. The health workers faced certain challenges such as the lack of proper building and sanitation at the Anganwadi Centre. The Anganwadi centres are in need of furniture, toys, water cooler, toilet, electricity and an almirah.

Image 7: FGD with Women's group at Anganwadi Centre in Selda and Dalchi



Source: IICA Survey, 2022

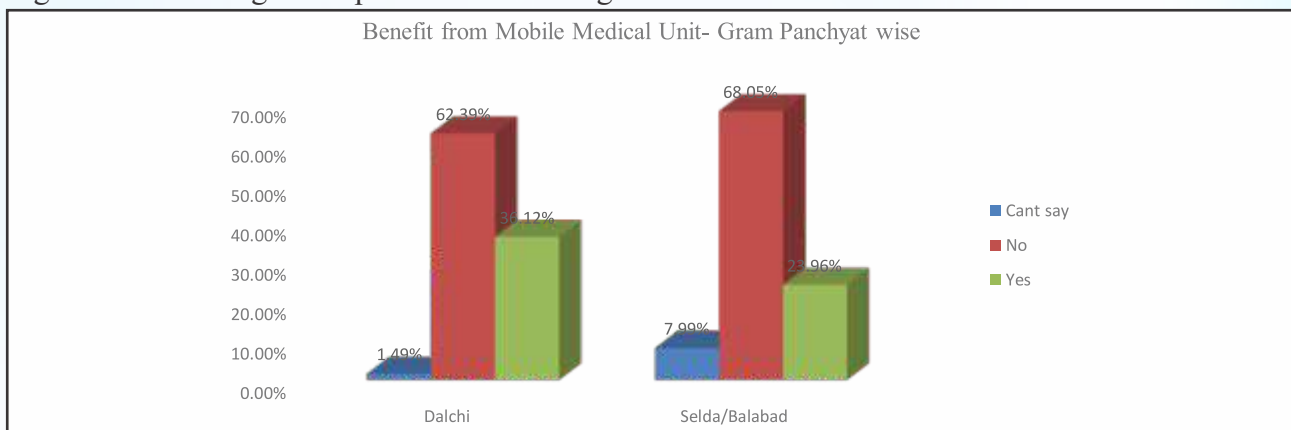
Mobile Medical Unit

Image 8: Mobile Medical Unit Van of NTPC Khargone



Source: IICA Survey, 2022

Figure 41: Percentage of respondents benefitting from mobile medical unit



Source: IICA Survey, 2022

As can be seen from the figure above, 36.12% respondents from Dalchi and 23.96% respondents from Selda/Balabad said that they have benefitted from the Mobile Medical Units by NTPC Khargone. The type of benefits as shared by the beneficiaries included basic check-ups, blood test and medicines.

Impact: The mobile medical units visit Selda and Dalchi twice a week and cater to the health needs of 46 villages. As per the data received from NTPC Khargone, on an average, 1400 people benefitted from MMU facility. The mobile medical units provide free consultation, medicines and pathological investigations at the doorstep of the beneficiaries. Several benefits are associated with mobile medical units such as preventing high cost healthcare expenditure of BPL groups, saving daily wages, travelling cost of patients staying in remotest locations, and primary healthcare service at the doorstep of vulnerable and marginalized communities. Also, when compared with the Socio-Economic Study/baseline data for KgSTPP, 2011, according to which there were no health facilities in Selda/Balabad and Dalchi and the people faced many challenges in accessing the medical facilities located at far off distance, the mobile medical units by NTPC Khargone is a boon. It is one of the most important and relevant interventions for improving the health of the people in the surveyed area.

Relevance: The concept of mobile medical units/vans is highly relevant in areas where medical infrastructure is sparse. They provide primary, preventive, curative health care services, thereby transforming the rural healthcare landscape by making primary care accessible in inaccessible areas.



Effectiveness: As the majority of respondents (65.2%) spread across Selda (68.05%) and Dalchi (62.39%) said that they did not benefit from the mobile medical unit provided by NTPC Khargone, it can be said that the health intervention has been ineffective in including a large number of villagers.

Sustainability: The mobile medical unit cannot be operated without the continued financial support from NTPC Khargone. However, in order to increase its acceptability and reach amongst villagers, it is important to increase the frequency of visits of the mobile medical units to the project affected villages.

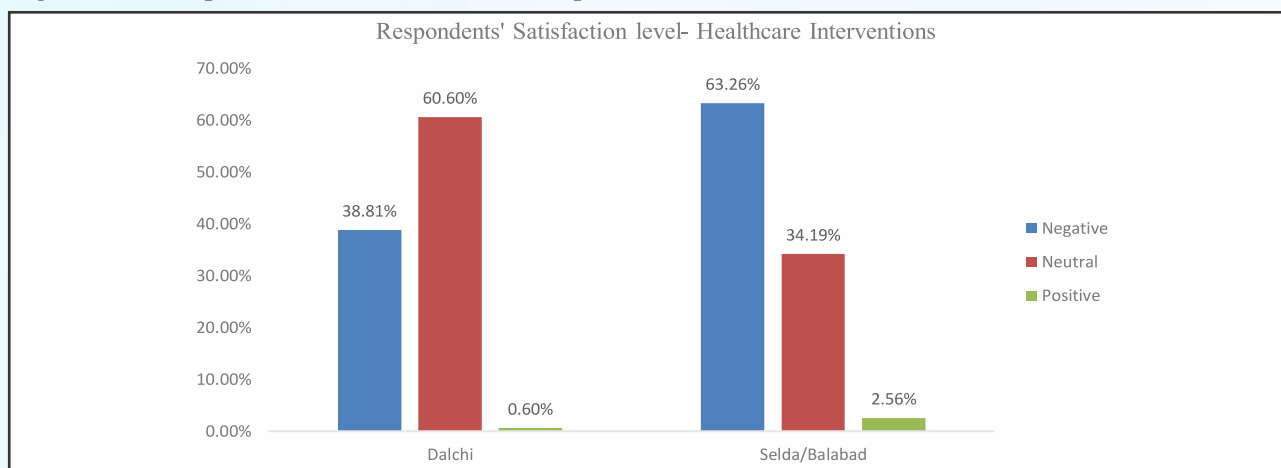
Furthermore, the Focus Group Discussions (FGDs) held in the surveyed gram panchayats Selda/Balabad and Dalchi revealed that despite the villagers having water pipes, the chemical pollutants in the water caused stomach pain, vomiting, diarrhea, acidity and even kidney stones. However, the communication with NTPC Khargone officials revealed that the district administration had instructed IIT Indore to investigate the presence of chemical pollutants in the water. It was found that no chemical or water from the plant contaminated the water and/or land of the area. Furthermore, the results were re-evaluated by IIT Madras which confirmed the findings of IIT Indore. Moreover, at the time of pregnancy, the women shared that they have to travel a large distance for delivery as there are no medical facilities available to them locally.

The women informed that they used clothes during periods and not sanitary pads. Also, the adolescent school going girls shared that they did not get proper guidance and menstrual hygiene trainings. Furthermore, a majority of the participants during FGDs shared that many people including women go for open defecation due to which there is a lot of filth around the 'mohalla'. The people have to go to the jungle or some other place which is 1Km away for defecation. According to them, there is no proper drainage system available. The waste/sewage flows over the roads. All this affects the health of the people very badly. The women during Focus Group Discussions complained that the mobile health vehicle did not visit them.

Moreover, the participants of the study perceived that their health was impacted as a result of air pollution caused due to NTPC plant operations. However, IICA's communication with NTPC Khargone revealed that no air pollution occurred due to the latter. This is due to the fact that NTPC Khargone is a Super Thermal Power Project that uses FGD technology. Hence, there has been no registered incidence of air pollution in the surveyed area. Furthermore, the common diseases as shared by the people included malaria, diarrhea, typhoid, skin diseases and eye problem.

The following figure represents the perception and satisfaction of the respondents towards the healthcare interventions made by NTPC Khargone in Selda/Balabad and Dalchi including their associated hamlets.

Figure 42: Perception and satisfaction of the respondents towards the healthcare interventions



Source: IICA Survey, 2022

8.3 IMPACT OF INTERVENTION IN RURAL INFRASTRUCTURE

The beneficiary household surveys including both the PAPs and Non-PAPs were used to understand the impact of rural infrastructural interventions by NTPC Khargone. Additionally, the PRI representatives such as the Village Sarpanch (Chief) and Sadasya (Members) of Selda/Balabad and Dalchi were interviewed to get their perspective on the infrastructural interventions of NTPC Khargone. The following infrastructures

were assessed for their impact on the community:

- Community Centres
- Roads and Drains
- Gangour Ghat

Image 9: Gangour Ghat, Roads, and Community centre built by NTPC Khargone in PAVs



Source: NTPC Khargone

Impact: The community hall is used by the community people for holding their cultural and matrimonial functions. The constructed roads are used by all the villages for reaching hospitals, schools, markets and other community spaces. Further, 'Gangour' is the most important festival celebrated in Khargone district of Madhya Pradesh. The people in Selda and Dalchi celebrate the festival with great devotion and enthusiasm. Therefore, the renovation of Gangour Ghat has positively impacted the people in the survey area.

Relevance: The construction of community centre is relevant as the people using them mainly belong to the lower socio-economic strata, and therefore it helps them organize their family functions conveniently. Further, the construction of roads is relevant to the villagers as the enhanced connectivity helps the latter in reaching the different places with ease. The renovation and construction of Gangour ghat is highly relevant as it meets the religious and cultural needs of people in Selda and Dalchi.

Effectiveness: 24.23% respondents spread across Selda and Dalchi said that the community halls were available and adequate in meeting their needs, while 36.73% respondents said that the community hall were available but inadequate. Further, 39% respondents said that a community hall was not available in their community.

53.24% respondents spread across Selda/Balabad and Dalchi shared that an all- weather or pucca (concrete) road was available to them. Further, the surveyed gram panchayat also had kutchha and kharanja roads. A total of 52.62% respondents across Selda/Balabad and Dalchi shared that Kutchha road existed in their village. Coming to the drainage system in the surveyed area, only 12.04% respondents shared that a sewage pipe/drainage system existed while a larger majority of respondents (77.16%) said that the water from their bath and kitchen area was released in the open and on the roads. Around 10.19% respondents said that the dirty water from their houses released into the fields.

On the question of the infrastructural interventions made by NTPC Khargone, the villagers did not specifically mention Gangourghat built by NTPCKhargone, though they mentioned about pucca roads, drains and community centres. However, one of the Sarpanch (Village Chief) at Selda/Balabad appreciated for building/renovating the Gangour Ghat. Further more, the majority of the PRI representatives did not acknowledge the infrastructural interventions of NTPC Khargone and said that the latter did not make

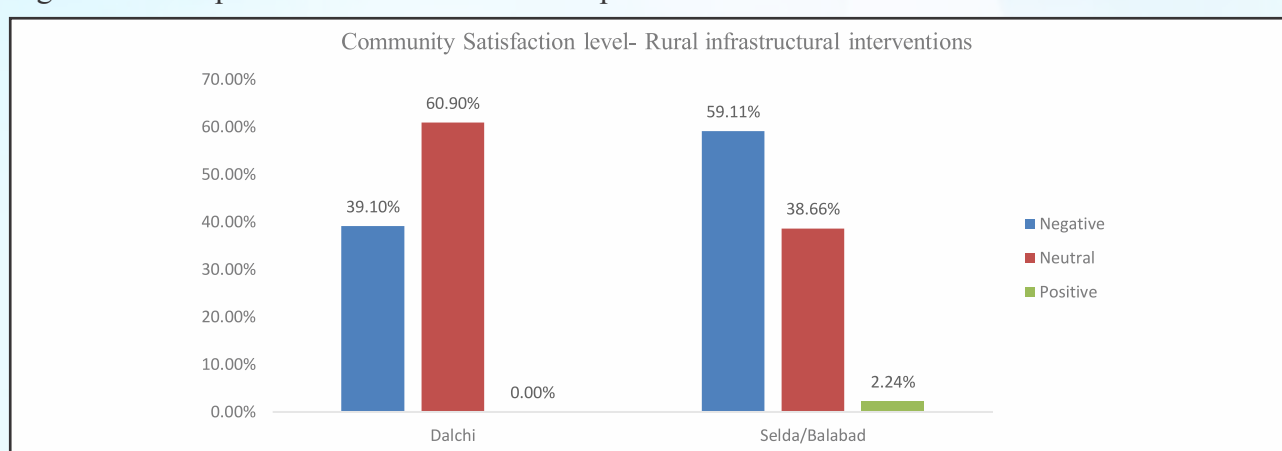


any contribution in the rural development of their Gram Panchayat. However, IICA's communication with the NTPC Khargone officials revealed that the Gram Panchayats send a “Tharv Prastav” duly signed by the representatives for infrastructures to NTPC Khargone. So far, NTPC Khargone had addressed 80% of the infrastructure as requested through the “Tharv Prastav”. These include roads construction and community hall amongst others.

Sustainability: Since the quality of the infrastructure like concrete roads, Gangourghat and community hall is good, they are expected to last long. However, proper maintenance of the community assets requires ownership and commitment of the community members and the financial support from NTPC Khargone.

The following figure represents the perception and satisfaction of the respondents towards the rural infrastructural interventions made by NTPC Khargone in Selda/Balabad and Dalchi including their associated hamlets.

Figure 43: Perception and satisfaction of the respondents towards the rural infrastructural interventions



Source: IICA Survey, 2022

8.4 IMPACT OF INTERVENTIONS IN DRINKING WATER AND SANITATION

The beneficiary household survey and FGDs including both the PAPs and Non-PAPs were used to understand the impact of drinking water and sanitation interventions by NTPC Khargone. The following infrastructures were assessed for their impact on the community:

- Repairing of Toilets under SVA
- Piped drinking water supply in the Project Affected Villages

Impact: The provision of safe and quality drinking water impacts the overall health of the survey area. Despite the availability of water pipes, the respondents complained about the lack of clean water as a result of which they fell sick due to water borne diseases. The improved sanitation environment due to the availability of functional toilets improves the overall quality of life of people. However, the survey found that a significant number of respondents practiced open defecation.

Relevance: Piped water supply to households is highly relevant as it enhances the quality of life and health of people. Functional toilets are basic necessity of any household and therefore are highly relevant for the people in the survey area.

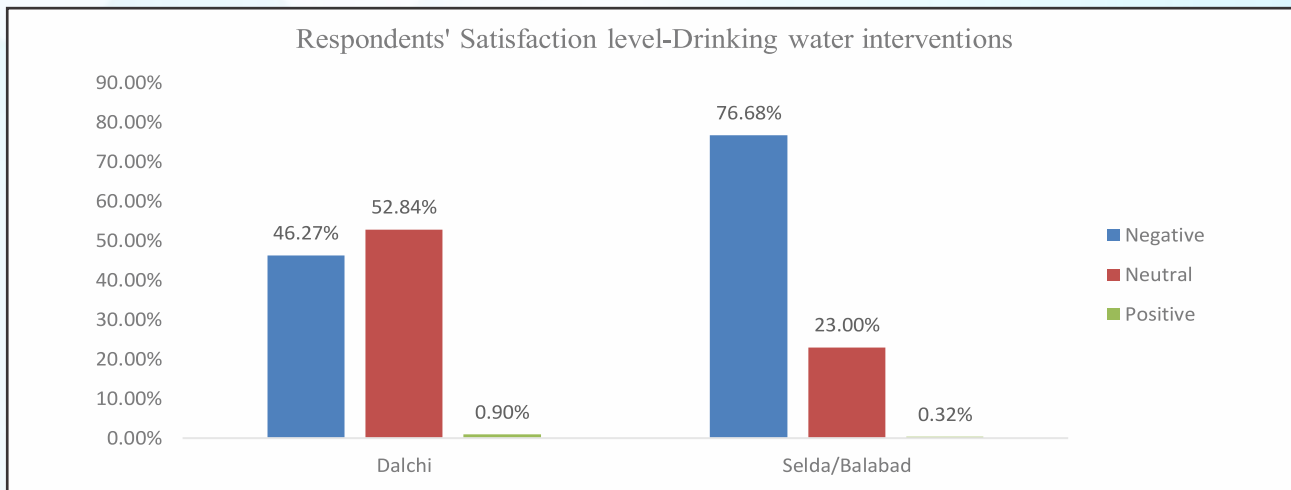
Effectiveness: 69.75% respondents spread across Selda (75.72%) and Dalchi (64.18%) have piped water connection in their household. While 64.81% respondents have appreciated the quality of water supply, 35.19% respondents said that the quality of drinking water was poor. Coming to the availability of toilets, 25.07% respondents in Dalchi and 75.72% respondents in Selda/Balabad said that they had a functional toilet with water supply in their household. However, it is important to note here that while

the Govt. of MP has declared Khargone district to be open defecation free, the IICA Survey found that 74.93% respondents in Dalchi and 24.28% respondents in Selda still practice open defecation.

Sustainability: The individual household toilets have to be maintained by the family members who use the same. However, the maintenance of community toilets and the toilets constructed at schools will require community involvement and financial support from NTPC Khargone.

The following figure represents the perception and satisfaction of respondents towards the drinking water interventions made by NTPC Khargone in Selda/Balabad and Dalchi including their associated hamlets.

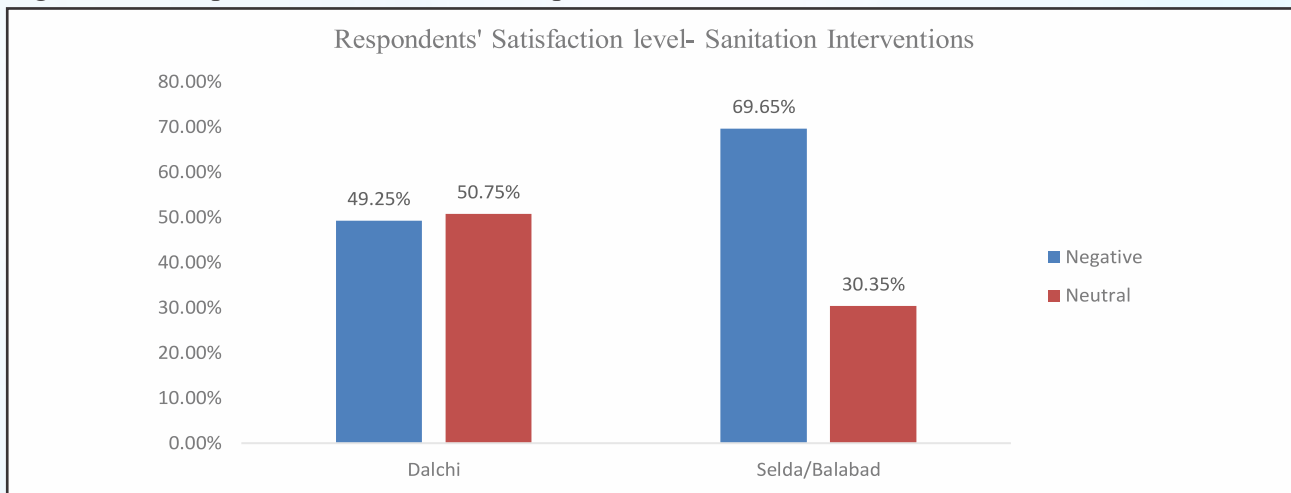
Figure 44: Perception and satisfaction of respondents towards the drinking water interventions



Source: IICA Survey, 2022

The following figure represents the perception and satisfaction of respondents towards the sanitation interventions made by NTPC Khargone in Selda/Balabad and Dalchi including their associated hamlets.

Figure 45: Perception and satisfaction of respondents towards the interventions in Sanitation



Source: IICA Survey, 2022

8.5 INTERVENTIONS IN SKILL DEVELOPMENT

The beneficiary household survey and FGDs including both the PAPs and Non-PAPs were used to understand the impact of skill development interventions by NTPC Khargone. Additionally, the PRI representatives such as the Village Sarpanch (Chief) and Sadasya (Members) of Selda/Balabad and Dalchi were interviewed to get their perspective on the skill development interventions of NTPC Khargone. NTPC Khargone provided the following opportunities to the people in the project affected villages.



- Dress Making training
- Empowering women through SHGs and providing capacity building training and helping them start their own enterprise on Masala powder and Pickles
- Other trainings

Impact: The skill development trainings facilitates in creating sustainable livelihood opportunities for the people in Project Affected Villages. NTPC Khargone provided training to the women in dress making (Stitching), Pickle and Papad making, and in beauty parlour. Additionally, it facilitated women in getting organized through SHGs. Further, it provided electrical and AC repair training to the youths. Rakhi training was also conducted in the survey villages. Computer training was organized for a few days in Selda and Dalchi. While the PRI representatives at Dalchi said that no skill development interventions were made by NTPC Khargone, the PRI representatives at Selda/Balabad shared that trainings were organized on stitching, electrical and agriculture. As per the data received from NTPC Khargone, more than 600 beneficiaries from Selda, Dalchi and Khedi Panchayat have undergone skill development training.

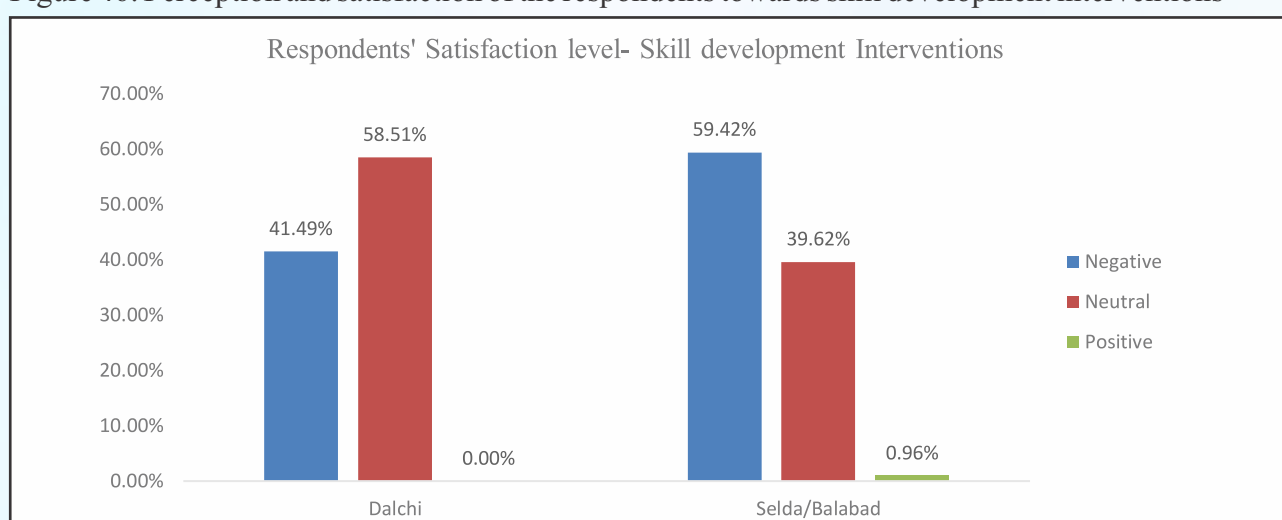
Relevance: 23.88% respondents in Dalchi and 21.33% respondents in Selda/Balabad said that the skill development training was beneficial for the youth of the village in getting employed or self-employed.

Effectiveness: Around 17.61% women in Dalchi and 15.02% women in Selda are associated to a Self-Help Group (SHG). Only 22.84% respondents spread across Selda (21.73%) and Dalchi (23.88%) said that they have received some form of skill development training.

Sustainability: The program is self-sustainable for women who have organized as SHGs and received training from NTPC Khargone. They can make and sell their products by running a shop within the NTPC Khargone Township. The profit can be saved in bank for buying raw materials and other items.

The following figure represents the perception and satisfaction of the respondents towards the skill development interventions made by NTPC Khargone in Selda/Balabad and Dalchi including their associated hamlets.

Figure 46: Perception and satisfaction of the respondents towards skill development interventions



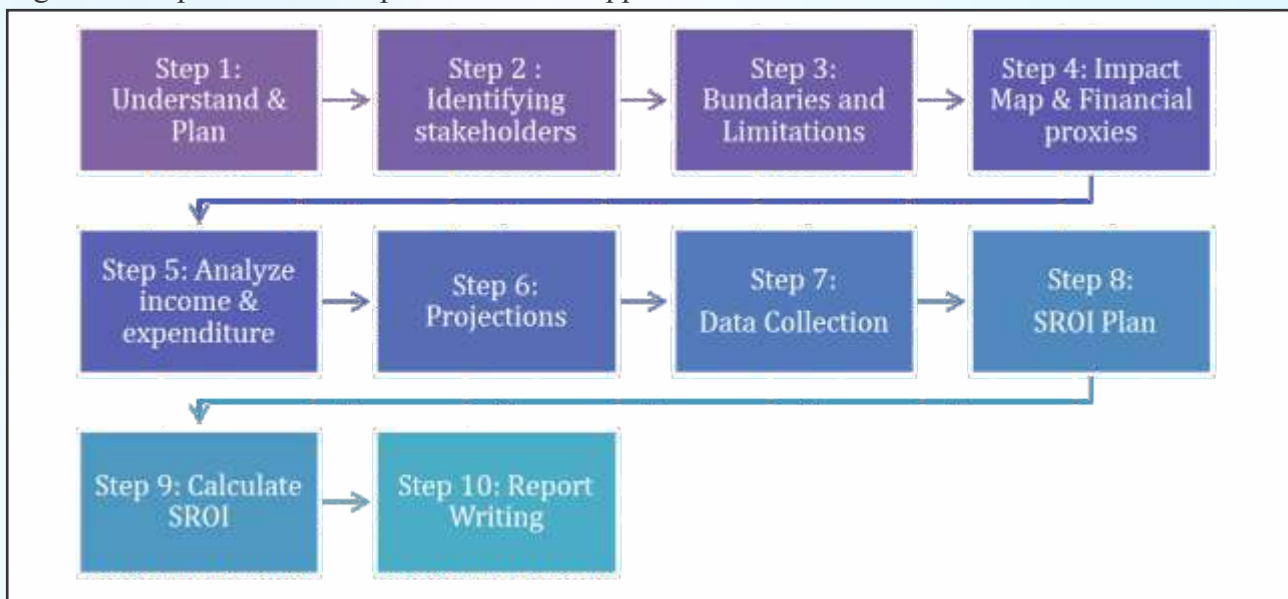
Source: IICA Survey, 2022

9. SOCIAL RETURN ON INVESTMENT

Step 1: SROI process and methodology

The objective of the study is to measure SROI value of R&R and CSR-CD projects implemented by NTPC near its plant in Khargone. The study will help NTPC Khargone in strategic planning and will help to compare the social value generated for different projects. The projects were analysed based on secondary information provided by NTPC field office and primary data collected from the field visit conducted in 2022, and the scope of study was established. The SROI study was carried out by IICA for all the CSR-CD activities undertaken by NTPC Khargone for its two project affected Gram Panchayats namely Selda/Balabad and Dalchi. The IICA follows a 10-step strategy given in Figure 46.

Figure 47: Steps in SROI Computation-IICA's Approach



(Source: IICA)

- 1. Understand and Plan:** The first step is the understanding the stages of the SROI study and planning the details of the SROI process. IICA accessed all the vital material and information on the nature and design of R&R projects, details of beneficiaries and implementing agencies and chalked out a plan to conduct the SROI analysis. A kick-off meeting was also done with the CSR team of NTPC| Khargone.
- 2. Identification of Stakeholders:** After understanding and planning, the stakeholders involved in the projects were identified. The identification of the stakeholders is a key step in the calculation of the SROI. Much care and attention was given in the identification of stakeholders. Only those stakeholders were included who had materially benefitted from the projects or had been associated directly or indirectly with the project.
- 3. Boundaries and Exclusions:** This step has two sub steps:
 - a. Materiality analysis:** The way of defining project 'materiality' to the SROI analysis is to evaluate whether a piece of information, if excluded, would significantly misrepresent the conclusions of CSR activities implemented by NTPC Khargone. In order to understand the biggest impact created, various factors were assessed such as Safety and wellness of school going children, sports interventions, toilet usage in the community, awareness of hygiene and sanitation among households, health care facilities, community support for hygiene and sanitation, provision and usefulness of skill development programs, provision of water, Usage of roads and its maintenance, usage of other infrastructure such as community centres etc. These criteria were used to assess the impact created under R&R interventions of NTPC Khargone.



b. Inclusion and Exclusion criteria: Based on the materiality analysis, the inclusion and exclusion criteria was applied to the CSR projects of NTPC Khargone and a short list of projects was developed. The concerned stakeholders of the selected projects were consulted for the SROI study.

4. **Impact mapping & financial proxies:** Once the R&R projects were shortlisted and stakeholders had been identified, the next step was to create an impact map. Project objectives, impact areas and nature of activities undertaken for projects were identified. Inputs, outputs, outcomes and impact were also outlined and a Theory of Change was formulated. The Theory of Change shows the inputs, outputs and outcomes as stated by different stakeholders. The nature of change that each stakeholder group undergoes was identified based on the theory of change to establish the relationship between inputs, outputs and outcomes for each project.
5. **Analyse Income & expenditure:** The materiality of the projects and the stakeholders is analysed by the amounts of expenditure incurred on the projects and the number of beneficiaries benefitted from the project.
6. **Projections:** From the expenditure data, it was ascertained whether the costs and benefits of the R&R projects may be projected over the future years. As advised by SROI experts, for the purpose of this study, projections of social values were taken for the next 5 years.
7. **Data collection:** Relevant data needed to calculate material change were identified and requested from NTPC Khargone. This involved developing outcomes, collecting relevant data, knowing duration of outcomes and weighing outcomes and then valuing them. Site visits of the villages under the CSR interventions of NTPC Khargone were also made to understand the impacts, determine proxy values and the perspective of various stakeholders for better estimation. This included one-on-one interactions, semi-structured interviews and focus group discussions with beneficiary and government officials.
8. **SROI plan:** The IICA team collected evidence on outcomes and monetized them, eliminating from consideration those aspects of change happening anyway or as a result of other factors. In cases where accurate data was not available, estimates were made by using proxies such as Government spending per person on Swachh Bharat Mission and fee of a school with good learning environment. By considering quantity of change and proxy values for each outcome, social value created was calculated and the value of deadweight and attribution was deducted from it.
9. **Calculating SROI:** In the last step, all project outcomes were added and various factors such as deadweight and attribution were subtracted and then the remaining value was divided by the total investment of NTPC Khargone on the projects. The contribution of the Government was also subtracted from NTPC Khargone investments to calculate the actual social value or SROI ratio. After the computation of the ratio, a sensitivity analysis was done to verify the results and their veracity. The aim of such an analysis is to test which assumptions have the greatest effect on the model. This allows us to report the amount of change necessary to make the ratio change from positive to negative or vice versa.

Once these calculations are done, the social value generated from the projects is calculated. The Social value is calculated by multiplying the financial value of outcomes with the total number of beneficiaries and then subtracting from it the deadweight, displacement, drop-off and attribution. The formula for the calculation of Social Value created is expressed as follows:

$$\text{Social Value Created} = \text{Outcomes} \times \text{Number of Beneficiaries} - (\text{minus}) \\ (\text{Deadweight} + \text{Displacement} + \text{Attribution} + \text{Drop-off})$$

After calculating the Social Value created through the projects, the next step is to compute the SROI ratio. The SROI ratio is computed by dividing the total social value created by the total amount of expenditure on the CSR projects. The formulae for calculating the SROI is expressed as follows:

SROI= Social Value Created/ NTPC Khargone R&R budget

The formulae stated above gives the SROI ratio for each project/thematic area which is the unit of analysis. The SROI value can then be analysed and suggestions and recommendations can be drawn from the resultant SROI. The SROI ratio shows the value of the impact which has been generated through R&R projects.

- 10. Report writing:** The reporting of the SROI value is done through standardized SROI reports which details the process and methods of calculation of the SROI. The reporting is done so that all the stakeholders can understand and verify the results.

Step 2: Scope of the study

The present study is the analysis of the Social Return on Investment of the R&R projects of NTPC Khargone. The R&R projects have been implemented in 2 gram panchayats named Selda and Dalchi in the vicinity of NTPC Khargone plant in Khargone District. The interventions have been categorized in seven thematic areas like Education, Healthcare, Water, Sanitation, sports, skill development Training and Infrastructure Development. The study analyses in detail the social return accrued because of R&R-CD projects. The study was done in consultation with the key stakeholders of the projects. The details of the projects and budgets incurred on them are given in the next section

Project Details and Budgets

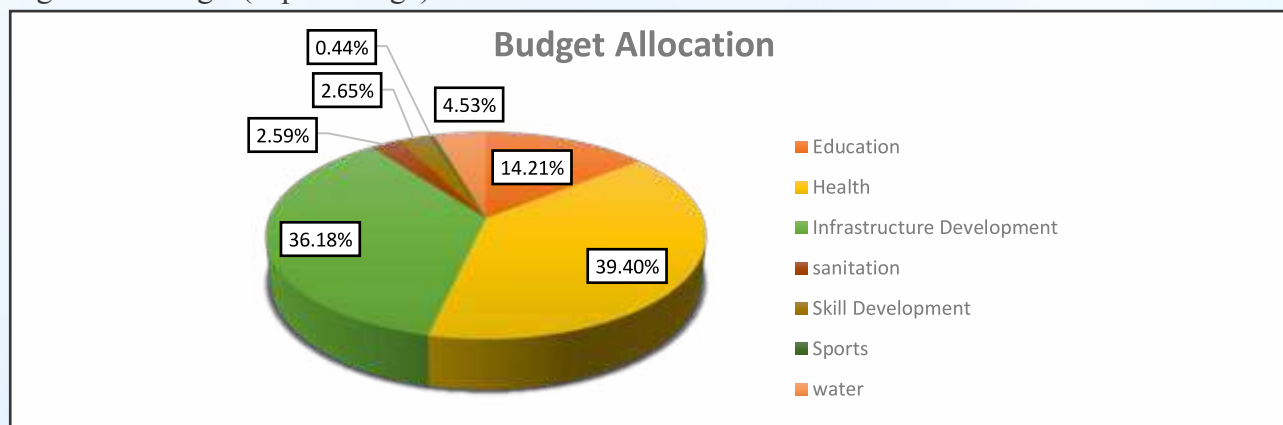
All the CSR activities implemented by NTPC Khargone are grouped together and classified under seven categories as listed below. These categories are in accordance with the R&R policy of NTPC:

1. Education
2. Healthcare
3. Sports
4. Skill development training
5. Water
6. Sanitation
7. Rural Infrastructure

Budget Allocation

Figure 47 shows that percentage of budget allocated to different thematic areas. Nearly 39% of the budget was allocated to the healthcare interventions, while 36% to infrastructure development. Interventions in education is another important area where allocation of budget is 14%. However, budget allocated for other important thematic areas like sanitation, water, sports and skill development is less than 10 per cent.

Figure 48 :Budget (in percentage)



Source: NTPC Khargone)



Step 3: Identifying stakeholders

The stakeholders are key to the SROI study. The consultation and engagement with all the stakeholders is needed to assess the impact of the study. Key stakeholders of these projects are identified and are given theme-wise in Table 6.

Table 6: Key Stakeholders

Thematic Areas	Key Stakeholders
Education	Students, Parents, School officials(teachers and principal), Gram Panchayat, BDO, NTPC officials
Healthcare	Community (Beneficiaries), Health officials, Gram Panchayat members and NTPC officials
Skill development Training	Trainees, Training Agency, Gram Panchayat members, NTPC officials
Water	Community (Beneficiaries), Gram Panchayat members, NTPC officials
Rural Infrastructure	Community (Beneficiaries), District Administration, Gram Panchayat members, NTPC officials
Sanitation	Community (Beneficiaries), District Administration, Gram Panchayat members, NTPC officials
Sports	Students, Parents, School officials(teachers and principal), NTPC officials

Step 4: Boundaries and Exclusions

It is important to assess and be clear about the boundaries and limitations of the study. At this stage, it is ensured that only those stakeholders and projects are considered for the study which are highly important and will impact the findings of the study, if left out.

Project stakeholders were consulted through focus group and one-to-one meetings in study area villages to understand the impact of the projects. Direct and indirect stakeholders comprehensively mentioned the change they have gone through in last few years due to NTPC Khargone's intervention in Health, Education, Water & Sanitation, Vocational training and Rural Infrastructure.

Consulting with various stakeholders through primary data collection exercise covered 680 households, 13 focus groups discussions in villages, and 32 interviews with key informants (Gram Panchayat Members, ANMs, Anganwadi workers, health officials and school officials) for monetizing outcomes. These were major primary stakeholders who were selected because they have undergone the material changes as per the objectives of the projects. Many outcomes emerged during the discussions but most relevant and significant outcomes which were experienced by most stakeholders were selected and monetized in the study.

In this stage, IICA determined the following:

- What is 'material' or important to include for decision-making purposes?
- Which stakeholders are we going to include and exclude?
- Which activities are we going to include and exclude?
- What data is available?

Materiality analysis: The way of defining project 'materiality' to the SROI analysis is to evaluate whether a piece of information, if excluded, would significantly misrepresent the conclusions of CSR activities implemented by NTPC Khargone. The materiality of the projects and the stakeholders is analysed by the amounts of expenditure incurred on the projects and the number of beneficiaries benefitted from the project. The excluded stakeholders of each thematic area are given in Table 7.

Table 7: List of excluded stakeholders

Focus Area	Excluded stakeholders	Reasons for exclusion
Rural Infrastructure	Construction Workers	List and contact details of construction workers who constructed roads and community structures not available
Sanitation	Construction workers	List and contact details of construction workers who repaired toilets not available
Water	District Water Board officials	Due to limited Scope of study
Skill development training	Trainers	List and contact details of trainers who trained the beneficiaries not available
Education	Construction workers	List and contact details of construction workers who constructed boundary walls and classrooms not available
Health	Doctors and staff	List and contact details of medical personnel catering to maternal and child healthcare not available
	Construction workers	Due to limited Scope of study
Sports	School Officials	Due to limited Scope of study

Some stakeholders like local Government officials have been excluded due to limited scope of study. However, in certain cases, the real behind exclusion of stakeholder is non-availability of data.

Step 5: Impact Mapping and Financial Proxies

Impact mapping is one of the most important elements of a SROI study. A Theory of Change is made through logical framework analysis to determine the impact of the interventions. At this stage, the inputs, outputs and outcomes are linked to visualize the impacts of the interventions. The details regarding the outputs, outcomes and impacts have been arrived at by consulting and communicating with the stakeholders identified in the previous section.

Impact Map and Financial Proxies of Educational Interventions

The outcomes of Educational Interventions lead to outcomes like improvement in academic performance of children, improvement in confidence of children, confidence and better teaching learning experience because of renovation of school infrastructure. The outcomes from educational projects for the parents are that it leads to an increase in confidence in their children and it also leads to an increase in self-esteem of parents. Table 8 summarizes the inputs, outputs and outcomes of educational interventions.

Table 8: Impact Map for Educational Interventions

Stakeholder	Input	Output	Outcome	Financial Proxy
Students	Time & Energy	No. of beneficiaries of Classrooms and school building constructed in schools	Improved quality and ambience for learning	average annual tuition cost, average cost of quality education
Students	Time & Energy	No. of beneficiaries of GEM Scholarship	Increased self-reliance and exposure of girls students	Average cost of month attending a one summer school
Students	Time & Energy	No. of students receiving school kits, benches and uniforms	Holistic development of students	average cost of benches, uniform, kits and cost of quality education
NTPC	Financial & Monetary Resources	NTPC branding	Improved Brand Image	1% Cost of brand improving exercises



The monetization of educational outcomes will be done on indicators like the cost of quality education that increases the motivation to continue the school, and the cost of yearly commute as financial proxies for increased self-confidence and self-esteem. The improved quality of education led to the savings on part of children and their parents for a life-skills session and of engaging a private school tutor. Hence, the financial proxy for this outcome can be the cost of attending a private tuition. This cost will be calculated and multiplied with the total number of beneficiaries to arrive at the social value of this project.

Impact Map and Financial Proxies of Healthcare Interventions

The outcomes of healthcare interventions as reported by Community are improved physical health owing to check ups, blood tests, medicines and money saved on travelling to nearest medical facility. Provision of mobile medical unit, maternal and childcare and improved services in the district hospital improved the NTPC Khargone's reputation and brand value in the community. Table 9 summarizes the inputs, outputs, outcomes and financial proxies of health interventions.

Table 9: Impact Map for Healthcare Interventions

Stakeholder	Input	Output	Outcome	Financial Proxy
Community members	Time & Energy	No. of beneficiaries who care and medical services at district hospital	Improved physical health of beneficiaries	average cost saved for medical consultation, medicine, travel expenses and time
Community members	Time & Energy	No. of beneficiaries who received doorstep medical facilities	Saved expenditure on travelling to nearest town	Average cost of travel to nearby district health facility
Community members	Time & Energy	No. of beneficiaries receiving women and childcare	Saved expenditure on maternal and childcare for 650 days	annual average cost for maternal and child care, savings in terms of travel, medicines and consultation
NTPC	Financial & Monetary Resources	NTPC Branding	Improved Brand Image	1% Cost of brand improving exercises

The financial proxies for the improved physical health of beneficiaries is taken equivalent to the average cost medical check-up per person and the average cost of travel to nearby district health facility. NTPC Khargone as a stakeholder also benefitted from the project, so the financial proxy for that outcome is the 1% cost of branding in the local newspaper.

Impact Map and Financial Proxies of Vocational Training projects

The skill development training led to employment of people and improvement in their livelihood conditions. The trainees reported to have improved self-esteem as a gainful employment because of the training. Table 10 summarizes the inputs, outputs, outcomes and financial proxies of vocational training interventions.

Table 10: Impact Map for Vocational Training Projects

Stakeholder	Input	Output	Outcome	Financial Proxy
Youth and women Beneficiaries	Energy & Time	No. of beneficiaries participated in various vocational trainings	Improved skills level for employment/ Self employment	average cost of attending classes, improved average yearly income, cost of certificate provided, salary of the trainers
NTPC	Financial & Human Resource	Completion of vocational training programmes	Improved NTPC brand image	1% of Advertisement cost

The vocational training leads to employment of the trainees and increase in the income of the households. This leads to many social benefits for the family and the households. The training also gives employment to the trainers and the implementation agency gets income through its engagement with the project. Financial proxy for the placement and employment of trainees is the average salary that they will receive after employment

Impact Map and Financial Proxies of Water

NTPC Khargone as part of their intervention in water projects renovated and upgraded water pipelines and constructed water tanks. It led to an increase in the improved quality and quantity of potable water available to households and also saving time which was earlier spent in carrying water from far-off places. It also improved access to safe drinking water to people of Selda and Dalchi. Table 11 shows the inputs, outputs, outcomes and financial proxies of water interventions.

Table 11: Impact Map of Water

Stakeholder	Input	Output	Outcome	Financial Proxy
Community Members	Time & efforts	No. of beneficiaries of water pipeline renovation and upgradation, construction of water tanks etc.	Improved access to safe drinking water	Average cost incurred on renovating and upgradation of water pipeline, buying water from other sources
NTPC	Financial & Human Resources	Renovation and upgradation of water pipeline, construction of water tanks etc.	Improved NTPC Brand Image	01% Cost of brand improving exercises

The outcomes of the water interventions have been monetized by using the financial proxy of average cost incurred on renovating, upgradation of water pipeline and buying water from other sources.

Impact Map and Financial Proxies of Sanitation Interventions

The sanitation intervention improved the difficulties of the people in repairing the toilets in the villages. The major outcomes of these projects are improved quality of life and sanitation facilities in the villages. Table 12 shows the inputs, outputs, outcomes and financial proxies of the sanitation interventions.

Table 12: Impact map for sanitation interventions

Stakeholder	Input	Output	Outcome	Financial Proxy
Beneficiaries (Community)	Time & Energy	No. of beneficiaries of toilets repaired	Reduced expenditure on health since excess to toilets improved, improved quality of life due to sanitation facilities	Average financial Savings due to reduced expenditure on health and average cost of repairing a toilet.
NTPC	Financial & Monetary Resources	Improved sanitation facilities through individual toilets built by NTPC		

Increased access to improved sanitation facilities and quality of life, reduced expenditure on health due to improved sanitation conditions, employment generated for construction workers are the major outcomes for this project. Quantification of reduced expenditure on health, average cost of building an individual toilet, average earnings for constructing a toilet has been used as financial proxies to monetize the outcomes of this project.



Impact Map and Financial Proxies of Infrastructure Development Interventions

These interventions about the development of infrastructures lead to outcomes such as easy and improved access to community buildings, Gangour Ghats, bus stands, roads, drains etc. This leads to employment and improvement of other facilities to the people. Better community infrastructure leads to general welfare and well-being. Table 13 shows the input, output, outcomes and financial proxies of the rural development interventions.

Table 13: Impact Map for Infrastructure Development Projects

Stakeholder	Input	Output	Outcome	Financial Proxy
Community/ Villagers	Time and Efforts	No. of beneficiaries of road construction, Gangour Ghats, drains, bus stands etc.	Easy access to towns, reduced time and improved medical savings.	Average cost of vehicle maintenance and fuel saving and average travel costs.
Community/ Villagers	Time and Efforts	Number of community members who benefitted from creation of community centre	Improvement in access to recreational opportunities	Average cost of renting a public place/banquet hall
NTPC	Time, Human Resource & Monetary resources	Completion of Rural Infra Projects	Improved NTPC Brand Image	1% Cost of brand improving exercises

The outcomes of the rural infrastructure interventions have been monetized by using the financial proxies such as average cost saved in the maintenance of vehicle and fuel savings, average cost of renting a public place/ banquet hall and 1% cost of advertisement gained by NTPC.

Impact Map and Financial Proxies of sports Interventions

These sports interventions lead to outcomes such as participation in various sports events and competitions. This leads to better opportunities to excel in sports and enhanced sportsmanship spirit. Table 14 shows the input, output, outcomes and financial proxies of the sports interventions.

Table 14: Impact Map for Sports Projects

Stakeholder	Input	Output	Outcome	Financial Proxy
Students	Time and Efforts	No. of beneficiaries receiving a platform to excel in sports	Easy access to block level tournaments & savings of travel costs.	Average cost of attending block level tournament and average travel costs.
Students	Time and Efforts	Number of beneficiaries having enhanced sportsmanship spirits	Creation of opportunities and awareness through the athletic meet	Average cost of attending an athletic meet
NTPC	Time, Human Resource & Monetary resources	Organisation of various sports meet	Improved NTPC Brand Image	1% Cost of brand improving exercises

The outcomes of the sports interventions have been monetized by using the financial proxies such as average fuel savings, average cost of attending an athletic meet and 1% cost of advertisement gained by NTPC.

Step 6: Establishing Impact

After ascertaining the outcomes and monetizing them based on financial proxies, valuation filters are used to adjust the return on investment against any impact which is not the outcome of the interventions under study. To ascertain the actual social value of the impacts, valuation filters like deadweight, attribution, drop-off and displacement are calculated and deducted from the total value of the impacts. This presents the correct view of the social value created through interventions. Table 15 gives the summary of the valuation filters used in the SROI.

Table 15: Summary of SROI Valuation Filters

Thematic Area	Average Deadweight	Average Attribution	Average Drop-off	Average Displacement
Education	13%	13%	15%	0%
Healthcare	15%	13%	13%	0%
Skill development Training	15%	15%	10%	0%
Water	25%	15%	15%	0%
Sanitation	30%	20%	5%	0%
Rural Infrastructure	20%	20%	13%	0%
Sports	17%	7%	13%	0%

Step 7: The SROI Computation

The final stage in the process is the computation of the SROI ratio and analysis of the outcomes. The SROI ratio is calculated by multiplying the quantity of outputs with the value of the financial proxies. After this, the value of the deadweight, attribution, displacement and drop off are subtracted from it. This brings us the value of outcomes of the interventions. The next step is to calculate the net present value of outcomes which gives us the clear picture of the value generated. The formula for the calculation of net-present value is as follows:

$$\text{Net Present Value} = [\text{Present value of benefits}] - (\text{minus}) [\text{Value of investments}]$$

Once the net present value of the outcomes is calculated, the SROI ratio is calculated by dividing the net present value by the value of total inputs.

$$\text{Net SROI ratio} = \text{Net Present Value of Outcomes} / \text{Value of inputs}$$

Table 16 gives a theme-wise summary of the SROI of various interventions made by NTPC Khargone.

Table 16: SROI of various thematic areas

Thematic Area	Budget (in percentage)	SROI Value
Healthcare	39.4%	1.33
Skill development Training	2.65%	1.83
Water	5.53%	9.88
Education	14.21%	2.59
Sanitation	2.59%	1.72
Infrastructure Development	36.18%	1.49
Sports	0.44%	1.07
	Average SROI Value/ Mean Satisfaction Index	1.98

The average SROI is 1.98. This means that for every rupee spent by NTPC Khargone, benefits worth rupee 1.98 are generated for society.



Step 8: Sensitivity Analysis

The results presented in this SROI evaluation are based on variables according to available evidence including qualitative data on the experience of stakeholders. Despite rigorous data collection, analysis and calculation, the SROI ratio is still an estimate of true value to the community and is thus prone to error. The sensitivity analysis explores and tests these assumptions and variables to verify the results of the analysis. A theme-wise sensitivity analysis has been done to verify the results of the SROI. For each theme, the most important areas have been taken up for the study.

Educational Interventions

In these interventions, the deadweight, attribution and drop-off were tested along with values and number of beneficiaries.

Table 17: Sensitivity Analysis for Education Intervention

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming deadweight of 0% instead of 13%	2.89
Attribution	Assuming 0% attribution instead of 13%	2.89
Drop-off	Assuming 0% drop-off instead of 15%	3.14

The original calculated SROI value for the educational interventions is **2.59**. After changing the value of assumptions, it was found that the SROI values changed to a very limited extent. There were no huge fluctuations in the value of the SROI by changes in the assumptions. This proves that the initial assumptions and valuations are reasonable.

Healthcare Interventions

In healthcare interventions, the SROI value is **1.33**. To check the sensitivity of the value, the deadweight, attribution and drop-off will be tested along with values of other outcomes. After making modifications in rate of deadweight, attribution, and drop off. The change in SROI value is small compared to its base value. This proves that the initial assumptions and valuations are reasonable.

Table 18: Sensitivity Analysis for Healthcare

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming 0% deadweight instead of 15%	1.64
Attribution	Assuming 0% attribution instead of 13%	1.64
Drop-off	Assuming 0% drop-off instead of 13%	1.90

Skill development Training Interventions

In vocational training interventions, the SROI value is **1.83**. After making modifications in rate of deadweight, attribution, and drop off, the change in SROI value is small compared to its base value. This proves that the initial assumptions and valuations are reasonable.

Table 19: Sensitivity Analysis for Vocational Training Intervention

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming 0% deadweight instead of 15%	2.07
Attribution	Assuming 0% attribution instead of 15%	2.07
Drop-off	Assuming 0% drop-off instead of 10%	2.21

Interventions for Water Interventions

In interventions related to water, the SROI value is **9.88**. The change in SROI value is small compared to its base value. This proves that the initial assumptions and valuations are reasonable.

Table 20: Sensitivity Analysis of interventions for Water

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming 0% deadweight instead of 25%	14.09
Attribution	Assuming 0% attribution instead of 15%	11.00
Drop-off	Assuming 0% drop-off instead of 15%	12.02

Sanitation Interventions

In sanitation interventions, the SROI value is **1.72**. After making modifications in rate of deadweight, attribution, and drop off, the change in SROI value is small compared to its base value. This proves that the initial assumptions and valuations are reasonable.

Table 21: Sensitivity Analysis for Sanitation Intervention

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming 0% deadweight instead of 30%	2.71
Attribution	Assuming 0% attribution instead of 20%	2.15
Drop-off	Assuming 0% drop-off instead of 5%	2.00

Infrastructure Development Interventions

In rural infrastructure interventions, the SROI value is **1.49**. After making modifications in rate of deadweight, attribution, and drop off, the change in SROI value is small compared to its base value. This proves that the initial assumptions and valuations are reasonable.

Table 22: Sensitivity Analysis for Rural Infrastructure Interventions

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming 0% deadweight instead of 20%	1.86
Attribution	Assuming 0% attribution instead of 20%	1.86
Drop-off	Assuming 0% drop-off instead of 13%	1.81

Sports Interventions

In sports interventions, the SROI value is **1.07**. After making modifications in rate of deadweight, attribution, and drop off, the change in SROI value is small compared to its base value. This proves that the initial assumptions and valuations are reasonable.

Table 23: Sensitivity Analysis for sports Interventions

Tested Assumptions	Change in variable	Changed SROI
Deadweight	Assuming 0% deadweight instead of 17%	1.28
Attribution	Assuming 0% attribution instead of 7%	1.18
Drop-off	Assuming 0% drop-off instead of 13%	1.07

Thus, the sensitivity analysis explored how robust the SROI ratios are by adjusting variables in the calculation to establish how much change would reduce the ratio of return to 1:1. In conclusion, regardless of the extent to which the discounting factors or value propositions of major components are reinterpreted, the SROI of various thematic areas remains just acceptable.

Step 9: Analysis and Recommendations

The mean SROI value of the projects is 1.98. It shows a monetary value of the social impact (the benefit) of R&R-CD interventions of NTPC Khargone. It expresses material project outcomes as equivalent monetary values so that they can be compared with the cost of inputs. The social return of the projects were 1.98 times the amount of investments done by NTPC Khargone.



There were some limitations while conducting the SROI study. One of the major limitations of SROI is that it is difficult to compare results between organizations. Many organizations adopt different ways of analysis and reporting of the SROI study. There is also issues of focusing on certain aspects of the study which increase the SROI values and downplaying those areas which diminish the SROI score. This SROI study also had specific some limitation which are discussed below:

1. Lack of appropriate indicators to assess return on investment for specific projects.
2. High attribution overlap since most beneficiaries get these benefits from multiple sources like government and NTPC that contribute to returns;
3. Challenge to engage beneficiaries to discuss sensitive and often proprietary financial data; and
4. Lastly, the development outcomes and return on investment are not always applicable, especially in remote areas where implementation costs are high and development results are slow.

10. CONCLUSION AND RECOMMENDATIONS

CONCLUSION

A comprehensive impact analysis was done for the major CSR-CD projects of NTPC Khargone in the domain of education, health, rural infrastructure, drinking water, sanitation, and skill development. The impact, relevance, effectiveness and sustainability of each of the interventions were assessed. Furthermore, the Social Return on Investment (SROI) was calculated for each domain separately.

With respect to the educational interventions of NTPC Khargone, it was found that the latter has constructed school buildings, boundary walls, distributed uniforms, school bags, and stationary, renovated classrooms, provided merit scholarship to students, implemented Girl Empowerment Mission (GEM) workshop, installed SMART TVs in high school and organized EVOICE initiative amongst others. These educational initiatives by NTPC Khargone are highly relevant given the socio-economic condition of people in the project affected villages (PAVs). As a result of NTPC Khargone's interventions, the overall percentage of literate and educated people in the PAVs have improved from 67.44% (2011) to 74.69% (2022). However, the educational interventions of NTPC Khargone was perceived to be unsatisfactory by a majority of the respondents of the surveyed area.

The SROI for the educational interventions came out to be 2.59. This means that for every rupee spent by NTPC Khargone for the development of education, benefits worth rupee 2.59 are generated for the society.

With respect to the health interventions, it was found that NTPC Khargone undertook several initiatives with an aim to promote the healthcare situation in the Project Affected Gram Panchayats namely Selda/Balabad and Dalchi. These included mobile medical units, maternal and child health care, and health infrastructure development at district hospital Khargone amongst others. The health interventions of NTPC Khargone are highly relevant in the surveyed area when compared with the grave situation of health and hygiene in the PAVs in 2011. According to the Socio-Economic Study for KgSTPP, 2011, there were no medical facilities in the surveyed area and the general health and hygiene of the Project Affected Persons was poor. As the people faced many challenges in accessing the medical facilities located at far off distance, the mobile medical units by NTPC Khargone is a boon. However, these significant health interventions of NTPC Khargone was perceived to be unsatisfactory by a majority of the respondents of the surveyed area.

The SROI for the health interventions came out to be 1.33. This means that for every rupee spent by NTPC Khargone for the improvement of health of people in the surveyed area, benefits worth rupee 1.33 are generated for the society.

With respect to the infrastructural interventions, it was found that NTPC Khargone constructed the community centres, roads and drains, and Gangour Ghat amongst others. The rural infrastructures created by NTPC Khargone are highly relevant to the people in the surveyed area. It was found that the community centre was used by the community people for holding their cultural and social functions. The constructed roads are used by all the villagers for reaching hospitals, schools, markets and other community spaces. Gangour being the most important festival, the renovation of Gangour Ghat positively impacted the people in the survey area. When compared with the baseline data of 2011, IICA survey, 2022 found that the percentage of people who have access to concrete roads have increased in the past 10 years. However, there is scope of much more improvement as pucca or concrete roads was available to only 53 percent respondents. Despite the significant rural interventions of NTPC Khargone, a majority of the respondents of the surveyed area were found to be unsatisfied in the perception and satisfaction survey.

The SROI for the rural infrastructural interventions came out to be 1.49. This means that for every rupee spent by NTPC Khargone for the rural infrastructure development, benefits worth rupee 1.49 are generated for the society.



With respect to the drinking water interventions, it was found that NTPC Khargone renovated and upgraded the water pipeline, supplied water through tanker, and constructed water tank amongst others. The piped water supply to households is highly relevant as it enhances the quality of life and health of people. A majority of respondents spread across Selda and Dalchi have piped water connection in their households and also appreciated the quality of potable water. Compared to the baseline data, 2011, the water supply has improved significantly in the project affected villages.

The SROI for the water interventions came out to be 9.88. This means that for every rupee spent by NTPC Khargone for drinking water, benefits worth rupee 9.88 are generated for the society.

With respect to the interventions in sanitation, it was found that NTPC Khargone repaired the toilets for the people in the surveyed area. Functional toilets are basic necessity of any household and therefore are highly relevant for the people in the survey area. The IICA Survey, 2022 found that there has been a significant improvement in the percentage of households (76% respondents in Selda and 25% respondents in Dalchi) with functional toilets when compared with the baseline data, 2011 where only 14.71% of the households had separate and proper toilets. While it can be said that the level of hygiene and sanitation improved after NTPC Khargone's interventions, it may be noted that 75% respondents in Dalchi still practiced open defecation. Furthermore, it was found that a majority of respondents were unsatisfied with the sanitation interventions of NTPC Khargone.

The SROI for the interventions in sanitation came out to be 1.72. This means that for every rupee spent by NTPC Khargone for sanitation, benefits worth rupee 1.72 are generated for the society.

In order to enable people earn their livelihood, skill development training was provided to the youth and women in the surveyed gram panchayats by NTPC Khargone. The training included dress making (stitching), pickle and papad making, beauty parlour, electrical, rakhi making, computer, horticulture amongst others. These trainings are highly relevant in context of the socio-economic condition of the people in the PAVs. Furthermore, the IICA survey found that after NTPC Khargone's interventions, the percentage of working population in the PAVs have improved significantly in the past ten years i.e. from 2011(52.6%) to 2022 (75.47%). However, a majority of the respondents of the study were unsatisfied with the skill development interventions by NTPC Khargone.

The SROI for the skill development interventions came out to be 1.83. This means that for every rupee spent by NTPC Khargone for the development of skill of the youth and women in the surveyed area, benefits worth rupee 1.83 are generated for the society.


Based on the discussion above, it can therefore be concluded that as compared to 2011, there has been an improvement in the quality of life of the people in the surveyed area. This is proved by the fact that the overall SROI for all the CSR-CD projects undertaken by NTPC Khargone is 1.98. It means that for every rupee invested by NTPC Khargone for the development of the Project Affected Villages (PAVs), benefits worth rupee 1.98 are generated for the society.

RECOMMENDATIONS

The IICA recommendations may be incorporated in the future projects to ensure inclusivity, effectiveness, impact and sustainability of CSR-CD projects.

Strategic Recommendations

- **Ensure sustainability of project:** The long-term sustainability of interventions in CSR-CD is a complex and persistent challenge. First, before handing over any project to community, NTPC Khargone must ensure that it has got a buy in from the community and key stakeholders. In order to make the projects sustainable, it is important to integrate community and panchayat engagement, and converge with government schemes and programmes right from the beginning. Initially for two years, the project maintenance should be handled by NTPC Khargone. However,



NTPC Khargone should safeguard by sensitizing communities about community resources ownership and community participation for sustainability of projects. For example: To ensure sustainability of the infrastructure in schools, NTPC Khargone must take a written consent from the school management committee (SMC)/ school administration regarding the responsibility to manage and timely repair the assets created by NTPC Khargone for sustainable long-term use.

- **Pilot-based project:** It shall be recommended that initially short-term projects should be executed in villages as pilot projects to assess the viability of a project. This will ensure the project impact and pros/cons along.
- **Branding of NTPC Khargone projects:** It is recommended that CSR project of NTPC Khargone should have clear branding so that the nearby community is aware of the social initiatives undertaken by NTPC Khargone.
- **Monitoring and evaluation of CSR projects:** A clear monitoring and evaluation framework along with the appropriate tracking system may be developed to make the projects more efficient and impactful.
- **Promotion of formation of Village Development Committee (VDC):** NTPC Khargone may promote the formation of Village Development Committee that will have men and women from the community who are responsible for taking care of the assets created by NTPC Khargone. It is recommended that the village level elected governing body collect some small payments for the usage of community projects. This helps to keep a check on the usage of resources as well as builds a corpus for future Operations & Maintenance.
- **Dovetailing with government schemes:** NTPC Khargone may ensure that its CSR-CD activities are aligned with central, state governments and district administration schemes and programmes. It can even support important welfare scheme such as old age pension, widow pension, and other social welfare benefits to see to it that the risks and vulnerability of the people belonging to very vulnerable segments of the society are addressed.

Thematic area wise recommendations

Education

- **Provision of bicycles to girl students:** The IICA survey, 2022 found that the women lagged behind men in receiving school and college education. Also, at the higher educational level such as graduation, the women lagged behind men. Moreover, with respect to technical education like ITI, there were no women respondents in the surveyed gram panchayats. The provision of bicycles to girl students have proven to empower and educate rural girls across India. Bicycles have proven to be wheels of change, and evidence¹⁶ suggests they can successfully boost rural girls' enrolment in secondary school.
- **Provision of digital education:** The IICA survey, 2022 highlights that there are no computer labs and internet access in any of the school surveyed in Dalchi and only 11.1 per cent schools in Selda had computer labs and internet access. Thus, these are found to be an immediate requirement in the schools in the area. NTPC Khargone can provide digital infrastructure to schools in its operations area to positively impact the quality of education in the area.

¹⁶ Muralidharan, Karthik and Nishith Prakash. 2017, "Cycling to School: Increasing Secondary School enrollment for girls in India" American Economic Journal: Applied Economics, 9 (3): 321-50

- **Improvement in enrolment in higher education institutes through scholarships:** The IICA survey, 2022 found that only 2.47% respondents were graduates and 1.39% respondents were post graduates. NTPC Khargone may provide scholarship to students to continue higher education in Khargone that may encourage them to continue education.

Healthcare

- **Creating awareness for institutional birth:** The IICA Survey, 2022 found that both Selda/Balabad (50.80%) and Dalchi (25.97%) lag behind the National (61.90%), State (80.20%) and District benchmark (85.60%) for institutional delivery in a public health facility. Thus, NTPC Khargone can organise awareness campaigns on the importance of institutional deliveries so that the villages in the study area achieve 100 per cent institutional deliveries.
- **Establishment of a telemedicine centre in each project gram panchayat/village:** Telemedicine refers to the use of information technologies and electronic communications to provide remote clinical services to patients. Nowadays, more health care providers are offering to 'see' patients by computer and smart phone. Telemedicine, which enables video or phone appointments between a patient and their health care practitioner, provides health benefits and is convenient. Telemedicine carts usually come equipped with computers, monitors, keyboards, cameras, and mobile medical devices, like digital scopes and wearable monitors. Hospitals are also increasingly using technology like interactive patient engagement systems to improve patient education and streamline workflows. The IICA survey, 2022 found that 85% of the households in the surveyed gram panchayats had a mobile phone. Therefore, NTPC Khargone may establish as well as run a telemedicine center within every project villages.
- **Building more awareness about NTPC Khargone's mobile medical units' initiative:** As per IICA Survey, 2022, a majority of the respondents in the surveyed area shared that they did not benefit from the MMUs. Therefore, the frequency of visit of the MMUs to the target beneficiaries may be increased. Additionally, the villagers may be made aware of the significance and visit schedule of the MMUs so that they can utilize the opportunity and benefit from the initiative.


Drinking Water and Sanitation

Water

- **Increase in the percentage of households with piped water supply:** As per IICA Survey, 2022, 76% households in Selda and 64% households in Dalchi had access to piped water supply which is much higher than the national, state and district benchmark. However, the survey found that the households which did not have piped water supply met their water needs through hand pumps and well/river. A very less percentage of respondents also required to purchase water for drinking purposes. Therefore, to increase the piped water supply, NTPC Khargone can dovetail the 'Jal Jeevan Mission- Har Ghar Jal Scheme' of Government of India by providing drinking water supply through pipelines and functional household tap connection to every rural household by 2024.
- **Installation of community taps with RO filtration Water plants system:** While 64.81% respondents have appreciated the quality of water supply, 35.19% respondents said that the quality of drinking water was poor. NTPC Khargone may therefore install RO water plant with co-pay model in PAVs.

Sanitation

- **Construction of community toilets:** The IICA Survey found that 74.93% respondents in Dalchi and 24.28% respondents in Selda still practice open defecation. This is because only 25.07% respondents in Dalchi and 75.72% respondents in Selda/Balabad said that they had a functional toilet with water supply in their household. Therefore, NTPC Khargone may construct community toilets so that the gram panchayats become open-defecation free.

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- **Building awareness on usage of toilets:** Various studies highlight that the construction of toilets does not necessarily result in improved toilet usage. In order to reduce/end the incidence of open defecation, intensifying the Swachh Bharat Abhiyan, NTPC Khargone can support awareness-raising programmes in schools and other public places involving communities and local governments; raise awareness thorough mass-communication platforms with focus on excluded and marginalized social groups.

Skill development and livelihood

- **Empowering Self-help groups:** As found in IICA Survey, 2022, only around 17.61% women respondents in Dalchi and 15.02% women respondents in Selda are associated to a Self- Help Group (SHG). Women Self-Help Group (SHG) should be empowered through sensitization, exposure and trainings. NTPC Khargone can support SHGs with training in backward and forward linkages like marketing, branding and micro finance etc.
- **Vocational training:** The IICA Survey, 2022 found that only 22.84% respondents spread across Selda (21.73%) and Dalchi (23.88%) said that they have received some form of skill development training. People expressed their demand for attending vocational training courses. NTPC Khargone can identify skill training centres or Government run Industrial Training Institute (ITIs) in the Khargone district and can help the people in documentation and getting them enrolled in these centers. The fees can be co-funded by NTPC Khargone. NTPC Khargone in collaboration with PMKVY 3.0 scheme¹⁷ can train the youths in order to help them secure better livelihood opportunities.

Rural infrastructure development

- **Construction of drains:** As per the IICA survey, 2022, only 12.04% respondents shared that a sewage pipe/drainage system existed while a larger majority of respondents (77.16%) said that the water from their bath and kitchen area was released in the open and on the roads. Around 10.19% respondents said that the dirty water from their houses released into the fields. Since drainage is an important public health issue, NTPC Khargone may undertake building of drainage system in the villages where it is not available.
- **Construction of roads:** As per the IICA Survey, 2022, 53% respondents have shared that pucca or concrete roads was available to them. As road connectivity projects have significant socio-economic effects on the lives of beneficiaries, NTPC Khargone may undertake road construction to positively impact the life of people in PAVs.

¹⁷ <https://www.pmkvyofficial.org/about-pmkvy>

11. ANNEXURES

11.1 ANNEXURES 1: ECONOMIC STATUS

Indicator to measure keeping objective	Percentage of population living below national poverty line	% of population below BPL (% of households with BPL ration cards)	Per capita income (Average annual income)
Source of Information (Secondary survey, FGD,KII)	NITI Aayog SDG India Index 2.0	Antodaya 2019	MOSPI 2018-2019
India	21.92 (NITI Aayog SDG India Index 2019)	42.65 Antodaya 2019	Rs,1,26,,406 MOSPI 2018-19
Madhya Pradesh	31.65 (NITI Aayog SDG India Index 2.0)	45.42 Antodaya 2020	Rs 90998 MOSPI 2018-19
Khargone	Data not Available	Data not Available	Data not Available
Selda/Balabad	Data not Available	48.46%	Data not Available
Dalchi	Data not Available	51.54%	Data not Available

11.2 ANNEXURES 2: EDUCATION & VOCATIONAL SKILL STATUS

Indicator to measure keeping objective	% of children (6-14 years) attending the school-Rural	% of children (15-16 years) attending the school- Rural	% of girl child (15-16 years) attending the school- Rural	% of children drop out after grade 5 (Drop out rate upper primary 6-8)	Average annual drop out rate at secondary level (class 9-class 10)	% of population having higher education (Gross enrollment ratio in higher education 18-23 yrs)
Source of Information (Secondary survey, FGD,KII)	ASER Report (2018)	ASER Report (2018)	ASER Report (2018)	UDISE Report 2019_20	NITI Aayog 2020 (SDG Index-Quality Education)	AISHE 2020
India	65.6% ASER Report (2018)	86.9 ASER Report (2018)	86.6 ASER Report (2018)	2.6 UDISE Report 2019_20	17.97 NITI Aayog 2020 Dashboard	27.1% AISHE 2020
Madhya Pradesh	95.8 ASER Report(2018)	76.6 ASER Report (2018)	73.2 ASER Report (2018)	4.1 UDISE Report 2019_20	24.85 NITI Aayog 2020 (SDG Index-Quality Education)	24.2 AISHE 2020

Khargone	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available
Selda/ Balabad	95.14%	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available
Dalchi	87.92%	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available

11.2.1 ANNEXURES 2: EDUCATION & VOCATIONAL SKILL STATUS

Indicator to measure keeping objective	Training and Skills available to people	% of youth (15-35 years) provided training/vocational for employment placement and/or self employment	Number of primary school/thousand population and average distance to nearest school	% of Children (15-18 years) attending the high school	% of girl child (15-18 years) attending the high school	Literacy rate of 7 plus year old (average literacy rate)
Source of Information (Secondary survey, FGD,KII)	Data not available	Data not available	MOSPI NSS 71ST Round	NITI Aayog 2015-16	NITI Aayog 2015-16	Census 2011
India	Data not available	Data not available	Less than 1 km	32.3% NITI Aayog 2015-16	32.67% NITI Aayog 2015-16	72.98 Census 2011
Madhya Pradesh	Data Not Available	Data Not Available	Data Not Available	Data Not Available	Data Not Available	69.24 Census 2011
Khargone	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available
Selda/ Balabad	6.35%	Data not Available	Data not Available	80.41%	77.78%	Data not Available
Dalchi	6.57%	Data not Available	Data not Available	53.98%	52.38%	Data not Available

11.3 ANNEXURE 3: HEALTH ISSUE IN THE COMMUNITY

Indicator to measure keeping objective	Under-five mortality rate per 1000 live birth (Under five mortality rate)	Percentage of children age 9-11 months fully immunized (BCG, measles, and 3 doses each of polio and DPT) (%) (Percentage of children age 9-11 months fully immunized)	Number of physicians, nurses, midwives	No. of beds per thousand population (Number of Government Hospitals and Beds in Rural & Urban Areas)	Tuberculosis (Total patients registered for treatment) (Total case notification rate of tuberculosis)	Malaria

Source of Information (Secondary survey, FGD,KII)	NITI Aayog (2020 SDG Index-Good Health and Well-being)	NITI Aayog (2020 SDG Index-Good Health and Well-being)	NITI Aayog (2020 SDG Index-Good Health and Well-being)	NHP 2020	NITI Aayog (2020 SDG Index-Good Health and Well-being)	NA
India	36 (2020 SDG Index-	91 NITI Aayog (2020 SDG Index-G	36.84 NITI Aayog (2020 SDG Index	818396 (NHP,2020)	177 NITI Aayog (2020 SDG Index-Good Health and Well-being)	Data not available
Madhya Pradesh	56 NITI Aayog (2020 SDG Index-Good Health and Well-being)	89 NITI Aayog (2020 SDG Index-Good Health and Well-being)	32.84 NITI Aayog (2020 SDG Index-Good Health and Well-being)	31106 (NHP,2020)	226 (2020 SDG Index-Good Health and Well-being)	Data not Available
Khargone	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available
Selda/Balabad	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available
Dalchi	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available	Data not Available

11.3.1 ANNEXURES

Indicator to measure keeping objective	Water borne diseases/ Prevalence of diarrhoea (reported) in the last 2 weeks preceding the survey (%) (children under age 5 years)	HIV(HIV Incidence rate)	Prevalence of underweight children under 05 years of age (Children under 5 years who are underweight)	Under five mortality rate per 1000 live birth (village wise)	Infant mortality rate per thousand birth
Source of Information (Secondary survey, FGD,KII)	Data not Available	NITI Aayog (2020 SDG Index-Good Health and Well-being)	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021

India	Data not Available	0.05 NITI Aayog (2020 SDG Index-Good Health and Well-being)	32.1 NFHS -5 2019-2021	41.9 NFHS-5 2019-2021	35.2 NFHS-5 2019-2021
Madhya Pradesh	Data Not Available	0.04 NITI Aayog (2020 SDG Index-Good Health and Well-being)	33 NFHS -5 2019-2021	49.2 NFHS-5 2019-2021	41.3 NFHS-5 2019-2021
Khargone	Data Not Available	Data Not Available	44 NFHS -5 2019-2021	Data Not Available	Data Not Available
Selda/ Balabad	Data Not Available	Data Not Available	Data Not Available	Data Not Available	Data Not Available
Dalchi	Data Not Available	Data Not Available	Data Not Available	Data Not Available	Data Not Available

ANNEXURE 11.3.2

Indicator to measure keeping objective	% of children immunized (Percentage of fully immunized children in the age group 0-5 years)	% of 1 year old children immunization (Children age 12-23 months fully immunized, BCG, measles and 3 doses each of polio and DPT)	Maternal mortality rate per lakh (village wise) (maternal mortality ratio)	Cancer	Disability(% of Differently abled person)
Source of Information (Secondary survey, FGD,KII)	NITI Ayog SDG Dashboard 2019	NFHS-5	NITI Aayog SDG Dashboard 2020	NHP 2020	Census 2011
India	59.2 NITI Aayog SDG Dashboard 2019	83.8	113 NITI Aayog SDG Dashboard 2020	67741 NHP 2020	2.21 Census 2011
Madhya Pradesh	62.8 NITI Aayog SDG Dashboard 2019	83.3	173 NITI Aayog SDG Dashboard 2020	4,119 NHP 2020	2.13 Census 2011
Khargone	Data Not Available	77.4	Data Not Available	Data Not Available	Data Not Available
Selda/ Balabad	Data Not Available	93.2	Data Not Available	Data Not Available	Data Not Available
Dalchi	Data Not Available	97.5	Data Not Available	Data Not Available	Data Not Available

ANNEXURE 11.3.3

Indicator to measure keeping objective	Number of people benefitted from distribution of ads and appliances (No of physically challenged received implants appliances)	No of Differently abled people enrolled in school (inclusive education) Differently abled children (5-19 years) attending educational institutions(%)GOAL 4 SDG
Source of Information (Secondary survey,FGD,KII)	Antodaya dashboard 2020	NITI Aayog SDG Dashboard 2019
URL link	https://missionantyodaya.nic.in/preloginStateSocialWeakerWelfareReports2020.html	https://sdgindiaindex.niti.gov.in/#/ranking
India	2275862 Antodaya dashboard 2020	61.18 NITI Aayog SDG Dashboard 2019
Madhya Pradesh	149992 Antodaya dashboard 2020	63.99 NITI Aayog SDG Dashboard 2019
Khargone	4180 Antodaya dashboard 2020	Data Not Available
Selda/Balabad	Data Not Available	Data Not Available
Dalchi	Data Not Available	Data Not Available

11.4 ANNEXURE 4 GENDER EQUALITY & WOMEN EMPOWERMENT

Indicator to measure keeping objective	Total number of SHGs promoted (Mobilized Into Self Help Groups (SHGs))Total number of SHGs promoted (Mobilized Into Self Help Groups (SHGs))	% of women in wage employment in the non- agricultural sector	% of seats held by women in government decision making bodies (Percentage of elected women over total seats in the state legislative assembly)
Source of Information (Secondary survey, FGD,KII)	Antyodaya Dashboard 2020 (Poverty Alleviation Programme)	Census of India 2011	NITI Aayog Dashboard 2020
India	26.1% Antyodaya Dashboard	28.2 Census 2011	8.46 NITI Aayog Dashboard 2020
Madhya Pradesh	14.1%Antyodaya Dashboard (Poverty Alleviation Programme)		9.13 NITI Aayog Dashboard 2020
Khargone	7.4% Antyodaya Dashboard (Poverty Alleviation Programme)	7.4% Antyodaya Dashboard (Poverty Alleviation Programme)	Data Not Available
Selda/Balabad	15.56%	Data Not Available	Data Not Available
Dalchi	17.61%	Data Not Available	Data Not Available

11.5 ANNEXURE 5 QUALITY OF LIFE

Indicator to measure keeping objective	Average out-of-pocket expenditure per delivery in a public health facility (Rs.)	Institutional births (%)	Institutional births in public facility (%)	"% of births attended by skilled health personnel Births assisted by a doctor /nurse /LHV/ANM/other health personnel (%) "	Child born at home but assisted by health care professionals . Home delivery conducted by skilled health personnel (out of total deliveries) (%)	Households with any usual member covered under a health insurance/ financing scheme (%)	Population living in households with electricity (%)
Source of Information (Secondary survey, FGD,KII)	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021
India	2,916 NFHS-5 2019-2021	88.6 NFHS-5 2019-2021	61.9 NFHS-5 2019-2021	89.4 NFHS-5 2019-2021	3.2 NFHS-5 2019-2021	41 NFHS-5 2019-2021	96.8 NFHS-5 2019-2021
Madhya Pradesh	1,619 NFHS-5 2019-2021	90.7 NFHS-5 2019-2021	80.2 NFHS-5 2019-2021	89.3 NFHS-5 2019-2021	2.5 NFHS-5 2019-2021	38.1 NFHS-5 2019-2021	98.4 NFHS-5 2019-2021
Khargone	1,657 NFHS-5 2019-2021	92.8 NFHS-5 2019-2021	85.6 NFHS-5 2019-2021	88.2 NFHS-5 2019-2021	1.3 NFHS-5 2019-2021	43.7 NFHS-5 2019-2021	98.8 NFHS-5 2019-2021
Selda/ Balabad	Data Not Available	Data Not Available	71.38%	Data Not Available	12.72%	Data Not Available	41.59%
Dalchi	Data Not Available	Data Not Available	46.13%	Data Not Available	28.04%	Data Not Available	14.63%

ANNEXURE 11.5.1 QUALITY OF LIFE

Indicator to measure keeping objective	Percentage of household with toilet facilities	Population living in households that use an sanitation facility (%)	Distance of the nearest hospital Average radial distance (Km) covered by PHC-Rural	% of households provided with piped drinking water (Percentage of households covered with piped drinking water)	% of population with sustainable access to improved water an source (within their premises and near to their premises) types of facility that is handpump, tap water well etc(Households with an improved drinking-water source (%))	% of population with pucca house (Percentage distribution of households living in Pucca houses)	% of population having house/ shelter (owning a house)
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Source of Information (Secondary survey, FGD,KII)	NSSO Survey NFHS-5 2019-2021	NFHS-5 2019-2021	RHS 2018-19	Antodaya dashboard 2020	NFHS-5 2019-2021	MOSPI NSS 76th round	MOSPI NSS 76th round NFHS-5 2019-2021
India	90% NSSO Survey	70.2 NFHS-5 2019-2021	6.18 RHS 2018-19	25.29 Antodaya dashboard 2020	95.9 NFHS-5 2019-2021	76.7 MOSPI NSS 76th round	96% MOSPI NSS 76th round
Madhya Pradesh	76 NFHS-5	65.1 NFHS-5 2019-2021	8.94 RHS 2018-19	14.5 Antodaya dashboard 2020	89 NFHS-5 2019-2021	59.5 MOSPI NSS 76th round	74 NFHS-5 2019-2021
Khargone	Data Not Available	73.8 NFHS-5 2019-2021	Data Not Available	35.9% Antodaya dashboard 2020	97 NFHS-5 2019-2021	Data Not Available	Data Not Available
Selda/ Balabad	75.87%	Data Not Available	Data Not Available	75.6% HH Survey	-	65.40%	Data Not Available
Dalchi	25.07%	Data Not Available	Data Not Available	64.20%	-	32.54%	Data Not Available

11.6 ANNEXURE 6 OTHERS

Indicator to measure keeping objective	Sex ratio of the total population (females per 1,000 males)	Sex ratio at birth for children born in the last five years (females per 1,000 males)	Women with 10 or more years of schooling (%)	Total Cultivable Area (in hectares)	Total irrigated land area (in hectare)	Total Unirrigated land area (in hectare)
Source of Information (Secondary survey, FGD,KII)	NFHS-5 2019-2021	NFHS-5 2019-2021	NFHS-5 2019-2021	Antyodaya Dashboard (Land Improvement and Minor Irrigation)	Antyodaya Dashboard 2020	Antyodaya Dashboard (Land Improvement and Minor Irrigation)
India	1020 NFHS 5 2019-2021	929 NFHS 5 2019-2021	41.0 NFHS 5 2019-2021	198100983.7 Antyodaya Dashboard 2020	75018663.7 Antyodaya Dashboard 2020	58663842.642 Antyodaya Dashboard 2020

Madhya Pradesh	970 NFHS 5 2019-2021	956 NFHS 5 2019-2021	29.3 NFHS 5 2019-2021	16939621.9 Antyodaya Dashboard 2020	7635483 Antyodaya Dashboard 2020	4867937.892 Antyodaya Dashboard 2020 (Land Improvement and Minor Irrigation)
Khargone	936 NFHS 5 2019-2021	1043 NFHS 5 2019-2021	27,2 NFHS 5 2019-2021	400058.9 Antyodaya Dashboard 2020	186344.2 Antyodaya Dashboard 2020	123163.8 Antyodaya Dashboard 2020
Selda/ Balabad	Data Not Available	Data Not Available	Data Not Available	Data Not Available	Data Not Available	0%
Dalchi	Data Not Available	Data Not Available	Data Not Available	Data Not Available	Data Not Available	0.56%

ANNEXURE 11.6.1 OTHERS

Indicator measure to keeping objective	No of Children (0-6 age group) receiving ICDS services (% of children in ICDS CAS)	% of eligible persons covered under Pradhan Mantri Suraksha Bima Yojana	% of eligible persons covered under Pradhan Mantri Jan Dhan Yojana (percentage of households covered with a bank account under PMJDY against target)	% of eligible persons covered under Atal Pension Yojana	% of eligible person covered under Pradhan Mantri Jeevan Jyoti Bima Yojana (Citizen enrolled under Pradhan Mantri Jeevan Jyoti Bima Yojana)	% of households provided food grains under PDS (% of Households receiving food grain from FPS)	% of eligible person enrolled under Aadhar (Percentage of population covered under Aadhar)	% of any other government schemes like Ujjwala Yojna (Number of Ujjwala beneficiaries)
Source of Information (Secondary survey, FGD, KII)	Antyodaya Dashboard 2019-20	HH Survey	NITI Aayog SDG Dashboard 2020	HH Survey	Transforming India my gov Dashboard	Antyodaya Dashboard 2019	NITI Aayog SDG Dashboard	Antyodaya Dashboard 2019
India	43% Antyodaya Dashboard 2019-20	Data not Available	99.99 NITI Aayog SDG Dashboard 2020	Data not Available	123799999 Transforming India my gov Dashboard	34 Antyodaya Dashboard 2019	93.24 NITI Aayog SDG Dashboard	49725237 Antyodaya Dashboard 2019

Madhya Pradesh	45.7% Antyodaya Dashboard 2019-20	Data Not Available	100 NITI Aayog SDG Dashboard 2020	Data Not Available	Data Not Available	41.8 Antyodaya Dashboard 2019	97 NITI Aayog SDG Dashboard	5346017 Antyodaya Dashboard 2019
Khargone	Data Not Available	Data Not Available	51.7% Antyodaya Dashboard	Data Not Available	Data Not Available	Data Not Available	Data Not Available	Data Not Available
Selda/ Balabad	Data Not Available	11.43%	5.71%	8.25%	5.71%	95.88%	96.19%	Data Not Available
Dalchi	Data Not Available	4.78%	4.48%	11.04%	2.69%	92.16%	95.22%	Data Not Available

11.7 ANNEXURE 7: SCHOOL INFRASTRUCTURE REQUIREMENTS

Name of the main village/GP	Name of the hamlet under main Village	Government High School	Pucca Building	Adequate Number of classroom	Boundary Wall	Blackboard in each classroom	Fan in each classroom	Play ground	Computer lab
Selda	Selda/balabad	Government High School	Yes	No	Yes	Yes	Yes	Yes	No
Selda	Seldabalabad	Government High School	Yes	No	Yes	Yes	Yes	Yes	No
Selda	Balabad	Government High School	Yes	Yes	Yes	Yes	Yes	Yes	No
Selda	Seldabalabad	Government Primary School	Yes	Yes	Yes	Yes	Yes	Yes	No
Selda	Seldabalabad	Government Primary School	Yes	No	Yes	Yes	Yes	Yes	No
Selda	Seldabalabad	Government High School	Yes	No	Yes	Yes	Yes	Yes	No
Selda	Selda/balabad	Government High School	Yes	No	Yes	Yes	Yes	Yes	No
Selda	Selda/balabad	EGS lalyachapad	Yes	No	Yes	Yes	Yes	No	Yes
Selda	Lalyachapad	Government Middle School	Yes	Yes	Yes	Yes	No	No	No
Dalchi	Dalchi	Government primary school	Yes	No	Yes	No	Yes	No	No
Dalchi	Dalchi	Government Primary School	Yes	No	Yes	Yes	Yes	No	No
Dalchi	Bedipura	Government Primary School	Yes	No	Yes	No	No	No	No
Dalchi	Jamniya	Government Primary School	Yes	Yes	No	Yes	Yes	No	No
Dalchi	Nurufaliya	Government Primary School	Yes	No	No	Yes	No	No	No
Dalchi	Manjariymal	Government Primary School	No	No	No	No	No	No	No
Dalchi	Changdiyafaliya	UEGS changdiyafaliya	Yes	Yes	No	Yes	No	No	No
Dalchi	Changdiyafaliya	Changdiyafaliya	Yes	No	No	Yes	No	No	No

Annexure 11.7.1 School Infrastructure Requirements

Name of the main village/ GP	Name of the hamlet under main Village	Government High School	Ramp for Differently abled Children	Electricity Connection	Internet Facility	Separate Toilet for girls & boys	Desks & chair for all	Library in school	Science lab in School	Is the re anganwadi centre at	Dedicated drinking water supply
Selda	Selda/balabad	Government High School	No	Yes	No	Yes	Yes	No	No	No	No
Selda	Seldabalabad	Government High School	No	Yes	No	Yes	Yes	No	No	No	No
Selda	Balabad	Government High School	No	No	No	Yes	Yes	No	No	No	No
Selda	Selda/Balabad	Government Primary School	No	Yes	No	Yes	Yes	No	No	No	No
Selda	Selda/Balabad	Government Primary School	No	Yes	No	Yes	No	No	No	No	No
Selda	Selda/Balabad	Government High School	No	Yes	No	Yes	No	No	No	No	No
Selda	Selda/Balabad	Government High School	Yes	Yes	No	Yes	Yes	No	No	No	No
Selda	Selda/balabad	EGS lalyachapad	No	Yes	Yes	Yes	Yes	No	No	No	No
Selda	Lalyachapad	Government Middle School	Yes	No	No	Yes	Yes	Yes	No	No	No
Dalchi	Dalchi	Government Primary School	Yes	Yes	No	Yes	Yes	No	No	No	Yes
Dalchi	Dalchi	Government Primary School	Yes	Yes	No	Yes	Yes	No	No	No	Yes
Dalchi	Bedipura	Government Primary School	No	Yes	No	No	Yes	No	No	No	Yes
Dalchi	Jamniya	Government Primary School	No	Yes	No	Yes	Yes	Yes	No	No	No
Dalchi	Nurufaliya	Government Primary School	No	No	No	Yes	No	No	No	No	No
Dalchi	Manjariymal	Government Primary School	No	No	No	No	No	No	No	No	No
Dalchi	Changdiyafaliya	UEGS Changdiyafaliya	Yes	No	No	Yes	Yes	No	No	No	No
Dalchi	Changdiyafaliya	Changdiyafaliya	Yes	No	No	Yes	No	No	No	No	No

11.8 ANNEXURE 8: ANGANWADI CENTRES REQUIREMENTS

Name of the main village/ GP	Name of the hamlet under main Village	No of Anganwadi Centre	Overall Condition	Furniture	Toys and other	Water cooler	Toilet	Electricity
Selda	Davkarmohalla	2	Bad	Yes	Yes	Yes	Yes	Yes
Selda	Balawad	2	Very Bad	Yes	Yes	Yes	Yes	Yes
Selda	Balabad	2	Bad	Yes	Yes	Yes	Yes	Yes
Selda	Balabad/selda	2	Bad	Yes	Yes	Yes	Yes	Yes
Dalchi	Dalchi	1	Bad	Yes	Yes	Yes	Yes	Yes
Dalchi	Dalchi	1	Bad	Yes	Yes	Yes	Yes	Yes
Dalchi	Nurufaliya	1	Bad	Yes	Yes	Yes	Yes	Yes

11.9 ANNEXURE 9: HEALTH CARE REQUIREMENTS

Name of the main village/ GP	Name of the hamlet under main Village	Health facility availability CHC/ NTPC hospital/ PHC	Health Facility availability: health centre/ dispensary/ hospital/ private clinic	Bed facility availability at the centre	Electricity	Clean Water	Seperate Toilets for male and female	Computer Facility	Lady Doctor	Ambulance
Selda/Balabad	Davkarmohalla	No	Yes	No	No	No	No	No	No	No
SeldaBalabad	Selda		Yes	Yes	Yes	No	No	No	No	No
SeldaBalabad	SeldaBalawad	No	Yes	No	No	No	No	No	No	No
Dalchi	Dalchi	No	Yes	Yes	Yes	Yes	No	No	No	No

Education

Stage 1		Stage 2				Stage 4						Calculating Social Return						
Source		At what cost?	How much?		How long?		How valuable?	How much caused by the activity?				Still material?	Calculating Social Return					
		Inputs	Quantity (scale)	Amount of change per stakeholder (depth)	Duration of outcomes	Outcomes start	Value in currency	Deadweight %	Displacement %	Attribution %	Drop off %	Impact calculation	Discount rate 3.5%					
Project	Beneficiaries	Financial value (for the total population for the accounting period)	Number of people experiencing described outcome.	Financial Proxy	How long (in years) does the outcome last for?	Does the outcome start in Period of activity or in the Period after?	How important is the outcome to stakeholders (expressed in monetary terms)?	What will happen/what would have happened without the activity?	What activity would/did you displace?	Who else contributed to the change?	Does the outcome drop off in future years?	Number of people (quantity) times value, less deadweight, displacement and	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
construction of school buildings, additional classrooms, school boundary walls, playgrounds etc.	school students, parents	10703000	2153	average annual tuition cost, average cost of quality education	5	period after	5,000.00	10%	0%	10%	10%	87,19,650.00	0.00	87,19,650.00	78,47,685.00	70,62,916.50	63,56,624.85	57,20,962.37
Girl Empowement Mission 2022	school students, parents	1250000	42	average cost of attending the one month summer school	2	period of activity	2,000.00	10%	0%	10%	10%	68,040.00	68,040.00	61,236.00	0.00	0.00	0.00	0.00
Distribution of School kit, benches and uniform to PAV's	school students, parents	1216000	635	average cost of benches, uniform, kits and cost of quality education	2	period of activity	1,000.00	10%	0%	10%	20%	5,14,350.00	5,14,350.00	4,11,480.00	0.00	0.00	0.00	0.00
	NTPC		1	1% cost of branding	5	period of activity	3,00,000.00	20%	0%	20%	20%	1,92,000.00	1,92,000.00	1,53,600.00	1,22,880.00	98,304.00	78,643.20	0.00
								0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
								0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1,31,69,000.00

Total	94,94,040.00	7,74,390.00	93,45,966.00	79,70,565.00	71,61,220.50	64,35,268.05	57,20,962.37
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Present value of each year	7,74,390.00	90,29,918.84	74,40,607.72	64,59,010.59	56,07,964.33	48,16,896.80
Total Present Value (PV)						3,41,28,788.27
Net Present Value (PV minus the investment)						2,09,59,788.27
Social Return (Value per amount invested)						2.59

Sanitation SROI

Stage 1		Stage 2						Stage 4										
Source		At what cost?	How much?		How long?		How valuable?	How much caused by the activity?				Still material?	Calculating Social Return					
Stakeholders		Inputs	Quantity (scale)	Amount of change per stakeholder (depth)	Duration of outcomes	Outcomes start	Value in currency	Deadweight %	Displacement %	Attribution %	Drop off %	Impact calculation	Discount rate		3.5%			
Project Name	Beneficiaries	Financial value (for the total population for the accounting period)	Number of people experiencing described outcome.	Financial Proxy	How long (in years) does the outcome last for?	Does the outcome start in Period of activity or in the Period after?	How important is the outcome to stakeholders (expressed in monetary terms)?	What will happen/what would have happened without the activity?	What activity would/did you displace?	Who else contributed to the change?	Does the outcome drop off in future years?	Number of people (quantity) times value, less deadweight, displacement and	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Repairing of Toilets	community	2400000	872	average cost of repairing toilets and money saved in terms of medical expenditures	5	period of activity	2,000.00	40%	0%	20%	10%	8,37,120.00	8,37,120.00	7,53,408.00	6,78,067.20	6,10,260.48	5,49,234.43	0.00
	NTPC		1	1% cost of branding	5	period of activity	3,00,000.00	20%	0%	20%	0%	1,92,000.00	1,92,000.00	1,92,000.00	1,92,000.00	1,92,000.00	1,92,000.00	0.00
								0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
								0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00

24,00,000.00

Total 10,29,120.00 10,29,120.00 9,45,408.00 8,70,067.20 8,02,260.48 7,41,234.43 0.00

Present value of each year	10,29,120.00	9,13,437.68	8,12,217.04	7,23,592.99	6,45,942.98	0.00
Total Present Value (PV)						41,24,310.70
Net Present Value (PV minus the investment)						17,24,310.70
Social Return (Value per amount invested)						1.72

Skill Training SROI

Stage 1		Stage 2						Stage 4						Calculating Social Return					
Source		At what cost?	How much?		How long?		How valuable?	How much caused by the activity?				Still material?							
Stakeholders		Inputs	Quantity (scale)	Amount of change per stakeholder (depth)	Duration of outcomes	Outcomes start	Value in currency	Deadweight %	Displacement %	Attribution %	Drop off %	Impact calculation							
Project Name	Beneficiaries	Financial value (for the total population for the accounting period)	Number of people experiencing described outcome.	Financial Proxy	How long (in years) does the outcome last for?	Does the outcome start in Period of activity or in the Period after?	How important is the outcome to stakeholders (expressed in monetary terms)?	What will happen/what would have happened without the activity?	What activity would/did you displace?	Who else contributed to the change?	Does the outcome drop off in future years?	Number of people (quantity) times value, less deadweight, displacement and attribution	Discount rate	3.5%					
												Year 0	Year 1	Year 2	Year 3	Year 4	Year 5		
Dressmaking, computer, horticulture, beautician, driving, electrical, rakhi making etc.	community	2456417	600	average cost of attending classes, improved average yearly income, cost of certificate provided, salary of the trainers	5	period of activity	2,000.00	10%	0%	10%	10%	9,72,000.00	9,72,000.00	8,74,800.00	7,87,320.00	7,08,588.00	6,37,729.20	0.00	
	NTPC		1	1% cost of branding	5	period of activity	3,00,000.00	20%	0%	20%	10%	1,92,000.00	1,92,000.00	1,72,800.00	1,55,520.00	1,39,968.00	1,25,971.20	0.00	
								0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
								0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		24,56,417.00										Total	11,64,000.00	10,47,600.00	9,42,840.00	8,48,556.00	7,63,700.40	0.00	
												Present value of each year	11,64,000.00	10,12,173.91	8,80,151.23	7,65,348.89	6,65,520.78	0.00	
												Total Present Value (PV)							44,87,194.81
												Net Present Value (PV minus the investment)							20,30,777.81
												Social Return (Value per amount invested)							1.83



Water SROI

Stage 1		Stage 2					Stage 4											
Source		At what cost?	How much?		How long?		How much caused by the activity?				Still material?	Calculating Social Return						
Stakeholders		Inputs	Quantity (scale)	Amount of change per stakeholder (depth)	Duration of outcomes	Outcomes start	Value in currency	Deadweight %	Displacement %	Attribution %	Drop off %	Impact calculation	Discount rate 3.5%					
Project Name	Beneficiaries	Financial value (for the total population for the accounting period)	Number of people experiencing described outcome.	Financial Proxy	How long (in years) does the outcome last for?	Does the outcome start in Period of activity or in the Period after?	How important is the outcome to stakeholders (expressed in monetary terms)?	What will happen/what would have happened without the activity?	What activity would/did you displace?	Who else contributed to the change?	Does the outcome drop off in future years?	Number of people (quantity) times value, less deadweight, displacement and attribution	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Renovation and upgradation of pipeline, water supply through tanker, construction of water tank etc.	community	4202000	4212	average cost saved for water pipeline upgradation and access to safe drinking water	5	period of activity	4,000.00	30%	0%	10%	10%	1,06,14,240.00	1,06,14,240.00	95,52,816.00	85,97,534.40	77,37,780.96	69,64,002.86	0.00
	NTPC		1	0.1% cost of branding	5	period of activity	3,00,000.00	20%	0%	20%	20%	1,92,000.00	1,92,000.00	1,53,600.00	1,22,880.00	98,304.00	78,643.20	0.00
					1			0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
					1			0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		42,02,000.00																
Total												1,08,06,240.00	1,08,06,240.00	97,06,416.00	87,20,414.40	78,36,084.96	70,42,646.06	0.00
Present value of each year												1,08,06,240.00	93,78,179.71	81,40,600.15	70,67,699.67	61,37,259.17	0.00	
Total Present Value (PV)																		4,15,29,978.71
Net Present Value (PV minus the investment)																		3,73,27,978.71
Social Return (Value per amount invested)																		9.88





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Ph:- 0124-2640000, Email:- contactus@iica.in



Ref: KGN/EMG/MOEF/Ann. Return/ACR 2025-26

Date: 06.04.2026

To
**Additional Principal Chief Conservator of Forests (C),
Ministry of Environment, Forest, and Climate Change,**
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3, Ravishankar Nagar,
Bhopal-462016, Madhya Pradesh
Email id- rowz.bpl-mef@nic.in
moefcc-coalash@gov.in

Sub: Submission of Annual Compliance Report for Ash Utilization for FY 2025-26

Ref: MOEF&CC, Notification S.O.-5481(E), dated 31.12.2021: Annual Compliance Report

Dear Sir,

With respect to the above-mentioned subject & reference, NTPC-Khargone Super Thermal Power Station is submitting herewith, **Annual Compliance Report (ACR)** of Ash Utilization in prescribed performa as **Annexure-1**, vide email for the period **1st April 2025 to 31st March 2026**.

Submitted for your kind information and perusal please.

Thanking you,

Yours Sincerely,

(Ashish Kumar Agarwal)
AGM (TS)

Enclosure:

1. Annexure-1: ACR of AU for FY 2025-26

Copy to (Email) :-

1. Member Secretary, CPCB, Delhi (mscb.cpcb@nic.in) (power.cpcb@gov.in)
2. Member Secretary, MPPCB, Bhopal (ms-mppcb@mp.gov.in)
3. Central Electricity Authority, (tcdcea@nic.in)
4. Regional Officer, MPPCB, Indore (ropcb-indore@mp.gov.in)

Ash Compliance Report
(for the period 1stApril'2025 to 31st March'2026)
(to be submitted on or before 31st May)

Ref.-MoEFCC Notification S.O. 5481(E), Dated-31.12.2021

S. No.	Details	Status
1	Name of Power Plant	Khargone Super Thermal Power Project
2	Name of the company	NTPC Ltd.
3	District	Khargone
4	State	Madhya Pradesh
5	Postal address for communication:	Village-Selda, PO-SPO NTPC-Selda, SO-Bediya, Tehsil-Barwah, District-Khargone, Madhya Pradesh, PIN-451113
6	E-mail:	emgkhargone@ntpc.co.in aukhargone@ntpc.co.in
7	Power Plant installed capacity (MW):	1320
8	Plant Load Factor (PLF %):	62.17
9	No. of units generated (MWh):	7188860.00
10	Total area under power plant (ha): (including area under ash ponds)	554.42
11	Quantity of coal consumption during reporting period MTPA (Metric Tons Per Annum):	4979935.00
12	Average ash content in percentage (percent):	47.97
13	Quantity of current ash generation during reporting period MTPA (Metric Tons Per Annum):	2388757.00
	Fly ash MTPA (Metric Tons Per Annum):	1672130.00
	Bottom ash MTPA (Metric Tons Per Annum):	716627.00
14	Capacity of dry fly ash storage silo(s) (Metric Tons) :	HCSD SILOS: 1500 (500 x 3) FLY ASH SILOS: 4000 (1000 x 4) Total Capacity: 5500
15	Details of utilisation of current ash generated during reporting period-	
a	Total quantity of current ash utilised (MTPA) during reporting period:	2402637.00
b	Quantity of fly ash utilised (MTPA):	
i	<i>Fly ash-based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels)</i>	183606.210
ii	<i>Cement manufacturing:</i>	1118990.458

iii	Ready mix concrete:	2431.42
iv	Ash and Geo-polymer-based construction material:	Nil
v	Manufacturing of sintered or cold bonded ash aggregate:	Nil
vi	Construction of roads, road and fly over embankment:	0
vii	Construction of dams:	Nil
viii	Filling up of low lying area:	Nil
ix	Filling of mine voids:	Nil
x	Use in overburden dumps:	Nil
xi	Agriculture:	Nil
xii	Construction of shoreline protection structures in coastal districts;	Nil
xiii	Export of ash to other countries:	Nil
xiv	Others (please specify):	Nil
c	Quantity of bottom ash utilised (MTPA):	
i	Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels):	163726.076
ii	Cement manufacturing:	3490
iii	Ready mix concrete:	Nil
iv	Ash and Geo-polymer based construction material:	Nil
v	Manufacturing of sintered or cold bonded ash aggregate:	Nil
vi	Construction of roads, road and flyover embankment:	930393.76
vii	Construction of dams:	Nil
viii	Filling up of low lying area:	Nil
ix	Filling of mine voids:	Nil
x	Use in overburden dumps:	Nil
xi	Agriculture:	Nil
xii	Construction of shoreline protection structures in coastal districts:	Nil
xiii	Export of ash to other countries:	Nil
xiv	Others (please specify):	Nil
	Total quantity of current ash Unutilised (MTPA) during reporting period:	Nil
16	Percentage utilisation of current ash generated during reporting period (per cent):	100.58
17	Details of disposal of ash in ash ponds	

a	Total quantity of ash disposed in ash pond(s) (Metric Tons) as on 31 st March (excluding reporting period):	405081.2
b	Quantity of ash disposed in ash pond(s) during reporting period (Metric Tons) :	1083730
c	Total quantity of water consumption for slurry discharge into ash ponds during reporting period (m ³):	3934100
d	Total number of ash ponds:	1 Ash Pond (with 03 Lagoons)
i	Active:	1
ii	<i>Exhausted (yet to be reclaimed):</i>	Nil
iii	<i>Reclaimed:</i>	Nil
e	Total area under ash ponds (ha):	132
18	Individual ash pond details <i>Ash pond-1,2, etc (please provide below mentioned details separately, if number of ash ponds is more than one)</i>	
a	Status: Under construction or Active or Exhausted or Reclaimed	Active
b	Date of start of ash disposal in ash pond (DD/MM/YYYY or MMYYYY):	01/08/2019
c	Date of stoppage of ash disposal in ash pond after completing its capacity (DD/MM/YYYY or MM/YYYY): (Not applicable for active ash ponds)	NA
d	Area (hectares):	132
e	Dyke height (m):	Variable height 15-18 m
f	Volume (m ³):	5990000
g	Quantity of ash disposed as on 31st March (Metric Tons):	391201.5
h	Available volume in percentage (percent) and quantity of ash can be further disposed (Metric Tons):	93.48 and 5598798.5
i	Expected life of ash pond (number of years and months):	NA (With Current Utilization Rate)
j	Co-ordinates (Lat and Long): (please specify minimum 4 co-ordinates)	22°04'36.8"N 75°50'52.2"E 22°04'26.4"N 75°49'59.9"E 22°04'42.4"N 75°50'18.2"E 22°04'20.3"N 75°50'23.6"E
k	Type of lining carried in ash pond: HDPE lining or LDPE lining or clay lining or No lining	L1-HCSD: Fly ash lining L2-BA & L3-BA: Bentonite clay lining

l	Mode of disposal: Dry disposal or wet slurry (in case of wet slurry please specify whether HCSD or MCSD or LCSD)	Wet and HCSD mode of disposal		
m	Ratio of ash: water in slurry mix	HCSD-55:45 & BA-20:80		
n	Ash water recycling system (AWRS) installed and functioning: Yes or No	Yes		
o	Quantity of wastewater from ash pond discharged into land or water body (m3):	Nil (Recycling Through AWRS)		
p	Last date when the dyke stability study was conducted and name of the organisation who conducted the study:	Lagoon 1-IIT Hyderabad -21.12-2021 Lagoon 2- IIT Hyderabad-21.12.2021 Lagoon 3-NIT Warangal-09.03.2025		
q	Last date when the audit was conducted and name of the organisation who conducted the audit:	11-10-2025, NIT Warangal		
19	Quantity of legacy ash utilised (MTPA):			
i	<i>Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels):</i>	NA		
ii	<i>Cement manufacturing:</i>	NA		
iii	<i>Ready mix concrete:</i>	NA		
iv	<i>Ash and Geo-polymer based construction material:</i>	NA		
v	<i>Manufacturing of sintered or cold bonded ash aggregate:</i>	NA		
vi	<i>Construction of roads, road and flyover embankment:</i>	NA		
vii	<i>Construction of dams:</i>	NA		
viii	<i>Filling up of low lying area:</i>	NA		
ix	<i>Filling of mine voids:</i>	NA		
x	<i>Use in overburden dumps:</i>	NA		
xi	<i>Agriculture:</i>	NA		
xii	<i>Construction of shoreline protection structures in coastal districts;</i>	NA		
xiii	<i>Export of ash to other countries:</i>	NA		
xiv	<i>Others (please specify):</i>	NA		
20	Summary:			
	Details	Quantity generated (MTPA)	Quantity utilised (MTPA) and (per cent)	Balance quantity (MTPA)
	Current ash during reporting period	2388757	2402530 & 100.58%	0
	Legacy ash	0	0	0

	Total	2388757	2402530 & 100.58%	0
21	Any other information: Soft copy of the annual compliance report, and shape files of power plant and ash ponds may be e-mailed to:- moefcc- coalash@gov.in	Noted		
22	Signature of Authorised Signatory	VIKAS KUMAR MEENA Digitally signed by VIKAS KUMAR MEENA Date: 2026.04.29 18:24:03 +05'30'		



प्रति,

श्रीमान सदस्य सचिव
मध्य प्रदेश प्रदूषण नियंत्रण बोर्ड
ई-5, अरेरा कालोनी, पर्यावरण परिसर,
भोपाल - 462016, मध्य प्रदेश
(Email- ms-mppcb@mp.gov.in)

विषय : वित्तीय वर्ष 2025-26 का पर्यावरणीय प्रतिवेदन (फार्म-V) प्रस्तुत करने हेतु।

महोदय,

एन. टी. पी. सी. लिमिटेड.- खरगोन सुपर थर्मल पावर प्रोजेक्ट द्वारा, वित्तीय वर्ष 2025-26 सम्बद्ध, वार्षिक पर्यावरणीय प्रतिवेदन, निर्धारित फार्म-V अनुसार आपके अनुमोदन हेतु प्रस्तुत है।

वार्षिक पर्यावरणीय प्रतिवेदन म प्र प्र नि बोर्ड के एक्स जी एन पोर्टल पर भी अपलोड कर दिया गया है।

सधन्यवाद,

(आशीष कुमार अग्रवाल)

अपर महाप्रबंधक (तकनीकी सेवाएँ)

संलग्न:

1. पर्यावरणीय प्रतिवेदन (फार्म-V), वित्तीय वर्ष 2025-26

प्रतिलिपि:

1. क्षेत्रीय अधिकारी, म. प्र. प्र. नि. बो., इंदौर, मध्य प्रदेश (Email-ropcb-indore@mp.gov.in)
2. सदस्य सचिव, के. प्र. नि. बो., दिल्ली (Email-mscb.cpcb@nic.in)
3. क्षेत्रीय कार्यालय, पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय, भोपाल, मध्य प्रदेश (Email-rowz.bpl-mef@nic.in)

Annual Environment Statement

FORM - V

(See rule 14)

Environmental Statement for the Financial year ending the 31st March 2026

PART - A

1	Name & address of the Owner/ Occupier of the Industry, operation or process.	Shri. Mohan Vattekkat (General Manager)	
		NTPC Ltd. Khargone Super Thermal Power Project	
		Vill.-Selda, Teh.-Barwah, Dist.-Khargone, Madhya Pradesh, PIN-451113	
2	Industry category Primary (STC Code), Secondary (STC Code)		
3	Production Capacity- Units	1320 MW (2 x 660 MW)	
4	Year of establishment	Date of Commissioning	
		Unit-I	29/9/2019
		Unit-II	24/3/2020
5	Date of last environmental statement	15 04 2025	

PART - B

Water & Raw material Consumption

1	Water Consumption m3/day process		
		During the previous financial year 2024-25	During the current financial year 2025-26
	Cat-I: Industrial Cooling	48250	46557
	Cat-I: Boiler feed	620	614
	Cat-I: Process-Ash Water	2146	853
	Cat.II: Domestic	938	934
	Cat-III: Process-water polluted,pollutants easily biodegradable	162	136
Water consumption per unit of products (m3/mwhr)			
	Name of Products	During the previous financial year 2024-25	During the current financial year 2025-26
	Electricity	2.56	2.74
2	Raw Material Consumption		
	Consumption of Raw Material Per unit of output		
	Name of Raw Materials	Name of Products	During the previous financial year 2024-25
			During the current financial year 2025-26
	Coal (kg/kwh)	Electricity	0.70
	Oil (ml/kwh)		0.20

PART - C

Pollution Generated

(Parameters as specified in the consent issued)

1	Pollutants	Quantity of pollutant discharged *	Concentration of Pollutants in discharges	Percentage of variation from prescribed standard with reasons
a	Water (Ann. Avg. of ETP treated effluents) (Kg/day)			
	pH (Limit: 5.5-9.0)	Not Quantifiable	7.49	Nil
	TSS (Limit: 100 mg/l max.)	Nil	4.6 mg/l	Nil
	BOD (Limit: 30 mg/l max.)	Nil	5.6 mg/l	Nil
	COD (Limit: 250 mg/l max.)	Nil	37.1 mg/l	Nil
	Oil&Grease (Limit: 10 mg/l max.)	Nil	<4 mg/l	Nil
	TDS (Limit: 2100 mg/l max.)	Nil	882.5 mg/l	Nil
	Chlorides (Limit: 1000 mg/l max.)	Nil	188.1 mg/l	Nil
	*No water discharged outside plant premises. Treated water reused in ash handling, dust supression, processes etc.			
b.	Air (Ann. Avg. of stack emissions) (MT/Yr.)			
	PM (Limit: 30 mg/nm3 max.)	128.1	7.73 mg/nm3	Nil
	SO2 (Limit: 100 mg/nm3 max.)	4518.6	272.56 mg/nm3	Nil
	NOx (Limit: 100 mg/nm3 max.)	4936.3	297.75 mg/nm3	Nil
	Hg (Limit: 0.03 mg/nm3 max.)	0.065	0.004 mg/nm3	Nil

PART - D

[as specified under Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016]				
1	Hazardous Wastes	Category	Total Quantity (in MT)	
			During the previous financial year 2024-25	During the current financial year 2025-26
a.	From Process			
	Used or Spent Oil	Sch.-I, Cat.-5.1	54.37 MT	11.52 MT
	Wastes or residues containing oil	Sch.-I, Cat.-5.2	Nil	Nil
	Spent ion exchange resin containing toxic metals	Sch.-I, Cat.-35.2	1.98 MT	1.99 MT
	Chemical Sludge from Water Treatment	Sch.-I, Cat.-35.3	Nil	Nil
	Empty barrels/containers/liners contaminated with hazardous chemicals/wastes	Sch.-I, Cat.-33.1	0.12 MT	9.38 MT
	Toxic- Insulation Glass Wool Waste	Sch.-II, Cat.-C4	20.76 MT	27.58 MT
b.	From Pollution Control Facilities		Nil	Nil

**PART - E
Solid Wastes**

1	Solid Wastes		Total Quantity (in MT)	
			During the previous financial year 2024-25	During the current financial year 2025-26
a.	From Process	Ash Generation	2264186	2388757
b.	From pollution control facility		Nil	Nil
c.	Quantity recycled or re-utilized	Ash Utilisation		
	Fly ash issue to Cement Plants		1133181	1121422
	Fly ash issue to Brick plants & Ash based product manufacturerurs		149028	183606
	Fly ash issue to Others-Traders		0	167216
	Pond ash to Road Projects		1310736	930393
	Pond ash in Ash dyke stabilisation		0	0
	Pond ash to Cement Plants		0	0
	Pond ash to Brick plants & Others		0	0
		Total	2592945	2402637

PART - F

Please specify the characteristics (in terms of concentration and quantum) of Hazardous as well as solid wastes and indicate disposal practice adopted for both these categories of wastes.

1	Hazardous Wastes	Composition	Quantum (Sanctioned) MT	Mode of disposal practice
	Used or Spent Oil (Sch.-I, Cat.-5.1)	-	70	Authorised Recycler with SPCB
	Wastes or residues containing oil (Sch.-I, Cat.-5.2)	-	10	Authorised Recycler with SPCB
	Chemical Sludge from Wastewater Treatment (Sch.-I, Cat.-35.3)	-	0.5	Through CTSDf
	Spent ion exchange resin containing toxic metals (Sch.-I, Cat.-35.2)	-	2	Authorised Recycler with SPCB/Through CTSDf
	Empty barrels/containers/liners contaminated with hazardous chemicals/wastes (Sch.-I, Cat.-33.1)	-	20	Authorised Recycler with SPCB/Through CTSDf
	Toxic- Insulation Glass Wool Waste (Sch.-II, Class C4)	-	100	Through CTSDf
2	Solid Wastes	Composition (% by Mass)	Quantum of disposal (MT)	Mode of disposal
	Ash	(approx.)	2402637	Soild waste as ash generated

[Handwritten signature]

Loss on Ignition	0.3		being utilised by issuing to cement plants, bricks & ash based product manufacturers etc. Balance quantities of unutilised ash disposed at ash dyke through network of pipelines.
SiO ₂ +Fe ₂ O ₃ +Al ₂ O ₃	92.9		
Magnesium oxide as MgO	0.65		
Sulphur as SO ₃	0.1		
Alkalies as Sodium Oxide Na ₂ O	0.1		
Chlorides	0.0		
Others	6.3		

PART - G

Impact of pollution control measures on conservation of natural resources and consequently on the cost of production

Pollution control and environment management measures adopted has resulted in general improvement in the quality of environment in and around the industry. In turn the cost of production generally increases but improves the quality of environment in the way of betterment for people, flora and fauna, are incomparable.

Pollution Control & Environment Management Measures		Cost Expenditure in 2025-26 (Rs. Lakhs)
1	Greenbelt development & Afforestation works	227.6
2	Environment monitoring works	4.7
3	Hydrogeology review study	13.9
4	Environment awareness & Other Env't. Expenditures	0.98
5	Waste Management Expenditures	8.5
Total		255.7

PART - H

Additional investment proposal for environmental protection including abatement of pollution

FGD: Flue Gas De-sulfurisation plants installed and available for both units for the control of SO_x emissions from stacks at an expenditure of Rs.68286.9 Lakhs

PART - I

Miscellaneous

Any other particulates in respect of environment protection and abatement of pollution.

1	Tree Plantation: 1. Cumulative 5.84 Lakh trees planted under Greenbelt/Roadside/Carbon Sink plantation inside and around project.
2	Ash Utilisation: 1. Complied 100% Ash Utilisation in FY 2025-26 i.e. 100.58 %


 (Ashish Kumar Agarwal)
 AGM (Ash & Env't. Mgmt.)
 Auth. Signatory

ए.के. अग्रवाल

अपर महाप्रबंधक (तकनीकी सेवाएं)
एनटीपीसी लिमिटेड, खरगोन (म.प्र.)

Water withdrawal data at NTPC-Khargone STPS

Source- Narmada River

Period- Oct'25-Mar'26 in FY: 2025-26

Water withdrawal data at NTPC Khargone STPP from Omkareshwar Dam on Narmada River				
Month	Start date	Finish date	Days	Water Drawn, m3
Oct 25	01 10 2025	31 10 2025	31	20,00,695
Nov 25	01 11 2025	30 11 2025	30	18,80,145
Dec 25	01 12 2025	31 12 2025	31	18,53,378
Jan 26	01 01 2026	31 01 2026	31	18,38,951
Feb 26	01 02 2026	28 02 2026	28	14,99,356
Mar 26	01 03 2026	31 03 2026	31	20,89,424
Total Water Drawn, m3				1,11,61,949

Total Water Withdrawal for Oct'25-Mar'26 - 1,11,61,949 m3



Ref: KGN/EMG/Ann. Comm./Ash Dyke Certification

Date-19.03.2026

To,
The Member Secretary
Central Pollution Control Board
Delhi
Email- mccb.cpcb@nic.in
power.cpcb@gov.in

Subject: Submission of Annual Certification of Ash Dyke for FY 2025-26

Ref: MoEF & CC Gazette Notification dated 31.12.2021 & its amendments

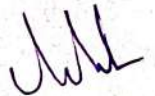
Dear Sir,

As per Clause-A (6), Ministry of Environment and Forest & Climate Change (MoEF&CC) Gazette Notification, annual certification of the ash pond or dyke shall be done by the thermal power plants as per guidelines issued by Central Pollution Control (CPCB) & Central Electricity Authority (CEA).

In compliance to the above, annual certification of ash dyke for the year 2025-26 has been conducted at NTPG-Khargone by an institute of repute, M/s Shri. G. S. Institute of Technology & Science (SGSITS), Indore.

Accordingly, Annual Certification Report of Ash Dyke as above is submitted herewith for your kind information and perusal please.

Thanking you,


(Ashish Kumar Agarwal)
AGM (Technical Services)

Enclosure:

1. Annual Certification of Ash Dyke Report for FY 2025-26

Copy to (Email):

1. MPPCB, Bhopal (Email- ms-mppcb@mp.gov.in)
2. MPPCB, Indore (Email- ropcb-indore@mp.gov.in)
3. MoEF&CC (rowz.bpl-mef@nic.in & moefcccoalash@gov.in)
4. CEA- (Email- tcdcea@nic.in)



Phone : 0731-2544415 (O)
Email : director@sgsits.ac.in
indoredirector@gmail.com
EPABX : 0731-2582101,112
Website : www.sgsits.ac.in

SHRI G.S. INSTITUTE OF TECHNOLOGY & SCIENCE

(Govt. Aided, UGC Autonomous Institute under 2(F) & 12(B), Established in 1952)
23, Sir M. Visvesvaraya Marg (Park Road), INDORE - 452 003 (M.P.) India
(Shri Govindram Seksaria Institute of Technology & Science, Indore M.P.)

Ref. :

Date :

CE-AMD/CONS/C-1343/SMN -SKA/2026/ 2967

13-03-2026.

14 MAR 2026

To

AGM Civil (O & M)
NTPC Khargone Super Thermal Power Project
Village-Selda, Post-Khedi (Bujurg)
Distt.-Khargone (MP) – 451113

Sub. : Report for Annual Certification of Ash Ponds and Dykes as per MOEF & CC guideline at NTPC Khargone (M.P.).

Ref.: Your Email Dated: 17-01-2026 and 29-01-2026 and Purchase Order No 8200463410-026-1054 dated 29-01-2026
Our letter No: CE-AMD/Consultancy/SMN-SKA/Quotation/2026/2604 dated 19-01-2026

Sir,

This has reference to your email/letter cited above; the report of the annual certification of ash ponds and dykes as per MOEF & CC and CPCB guidelines for NTPC Super Thermal Power Project, Khargone (M.P.) is attached herewith. With reference to the above, we are submitting herewith our observations, recommendations and checklist-(Annexure 1).

The consultancy charges of above work are Rs. 94,990/- (Consultancy fee 80,500 + 18% service tax (GST) 14,490/-). You are requested to make the payment of an amount of Rs. 94,990/- in account section of our Institute as soon as possible.

Your comments regarding the services provided by the Institute and your suggestions (if any) regarding the improvement for the same will be helpful to us.

Thanking you,

Yours Sincerely,


DIRECTOR


Encl.: Report and Annexure 1



Phone : 0731-2544415 (O)
Email : director@sgsits.ac.in
indoredirector@gmail.com
EPABX : 0731-2582101,112
Website : www.sgsits.ac.in

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(Shri Govindram Seksaria Institute of Technology & Science, Indore M.P.)

Ref. : CE-AMD/CONS/ C-1343/SMN -SKA/2026/ 2967

Date : 13-03-2026.

14 MAR 2026

REPORT ON

Annual Certification of Ash Ponds and Dykes for NTPC Khargone

Name of the Client : Additional General Manager Civil (O & M)
NTPC Khargone Super Thermal Power Project, Khargone (M.P.)
Name of the work : Annual certification of ash ponds and dykes as per MOEF & CC and
CPCB guidelines for NTPC Super Thermal Power Project,
Khargone (M.P.)
Reference : Your Email-Dated: 17-01-2026 and 29-01-2026 and Purchase Order
No 8200463410-026-1054 dated 29-01-2026.

The client has requested to conduct an annual certification of ash ponds and dykes as per MOEF & CC and
CPCB guidelines for NTPC Super Thermal Power Project, Khargone (M.P.).

The site was visited by our Experts:

Dr. S.M. Narulkar
Ph.D. in Water Resources Engineering
Professor, Water and Environmental Division
Department of Civil Engineering
Email: snarulkar@sgsits.ac.in, M. No 98260-83317

Dr. S.K. Ahirwar
Ph.D. in Geotechnical Engineering
Associate Professor, Geotechnical Division
Department of Civil Engineering
Email: sahirwar@sgsits.ac.in, M. No. 81698-45602

OBSERVATIONS:

The following observations were made during the visit held on 25-02-2026 at NTPC plant located
at Khargone.

1. The ash pond has been checked for all the parameters as required by the guidelines
provided by the CPCB, MoEF & CC as referred for period i.e. 1st April, 2025 to 31st
March, 2026.
2. The dyke was maintained well by taking all the necessary O&M activities by the
NTPC during the evaluation period.
3. The detailed observation checklist for annual certification is attached as an Annexure-1.

RECOMMENDATIONS:

Based on the field visit and records verification, the dykes are maintained well as per the O&M
guidelines provided by the regulatory authority.

Report Prepared by: Dr. S. M. Narulkar and Dr. S.K. Ahirwar.

(Dr. S. M. Narulkar)
Professor, CE-AMD

(Dr. S.K. Ahirwar)
Associate Professor, CE-AMD

(Dr. R. K. Khare)
Professor & Head, CE-AMD

DIRECTOR



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(Shri Govindram Seksaria Institute of Technology & Science, Indore M.P.)

14 MAR 2026
Annexure-1

Ref. :

Sr. No.	Component	Observations/Remarks Date :
1.	Name of Power Plant	Khargone Super Thermal Power Project (2 × 660 MW)
2.	Name of the company	NTPC Limited
3.	District	Khargone
4.	State	Madhya Pradesh
5.	Postal address for communication:	NTPC Limited, Khargone Super Thermal Power Project, Selda - Balabad, PO: Khedi - Bujurg, Teh. Bediya, Khargone - 451113
6.	E-mail:	hopkhargone@ntpc.co.in mvkulkarni@ntpc.co.in
7.	Power Plant installed capacity (MW):	1320 MW
8.	No. of units generated (MWh):	2 units
9.	Total area under power plant (ha): (including area under ash ponds)	Approx. 715 Ha
10.	Method of slurry discharge water consumption or conservation in disposal, ash water recycling	High concentrated slurry discharge Bottom ash slurry discharge Ash water recycling system operational
11.	TSS of decant Water (Going outside/for recirculation)	Within Limit
12.	Maintenance of Dyke. आचार: प्रथमो धर्म: 1. Top Width 2. Top level of dyke 3. Adequate Spillway Capacity 4. Free board 5. Available volume 6. Earth covering and turfing 7. U/S slope protection 8. WBM Road 9. Rock Toe, toe drain, berm, rock, pitching 10. Dyke compaction 11. D/S erosion control	For lagoons & OFL 1. 6 m 2. RL 250 m 3. Available 4. Available 1.5 m 5. Lagoon-1 = 23.21 LCM Lagoon-2 = 19.98 LCM Lagoon-3 = 12.0 LCM 6. Available 7. Available 8. Available 9. Available 10. OK 11. OK
13.	Instrumentation a) Piezometer, b) surface settlement	Available

Signature 2



Phone : 0731-2544415 (O)
Email : director@sgsits.ac.in
indoredirector@gmail.com
EPABX : 0731-2582101,112
Website : www.sgsits.ac.in

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23, Sir M. Visvesvaraya Marg (Park Road), INDORE - 452 003 (M.P.) India

(Shri Govindram Seksaria Institute of Technology & Science, Indore M.P.)

14 MAR 2026

Ref. :

Ref. :			Date :
14.	Wet Patches/softening on down Slope	None	
15.	Gully Formation	None	
16.	Rat holes/ animal burrows	None	
17.	Growth of plants	None	
18.	Toe drain and surface drainage system	Available	
19.	Facilities for inspection and maintenance of the dyke	Available	
20.	Flooding Lighting	Available	
21.	Seepage or Leakage	None	
22.	Monolith Joints -	Not applicable	
23.	Foundation should be examined for damage or possible undermining of the downstream toe	Examined. No damage or undermining is observed.	
24.	Slope Stability dyke: 1. Dyke Slope stability, as per IS 7894: Dyke structural stability to be examined as per construction drawings, quality control documents monitoring reports etc. 2. Dyke slopes should be examined for irregularities in alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks, which indicate movement.	Examined and found OK. Examined and found OK.	
25.	Condition of Drainage Systems	OK	
26.	Condition of Slope Protection	OK	
27.	Environmental Pollution	Under Control	
28.	Green belt	OK	
29.	Any other information: Soft copy of the annual compliance report, and shape files of power plant and ash ponds may be e-mailed to:- moefccoalash@gov.in	NTPC Khargone may send the documents stipulated to the authority mentioned.	
30.	Signature of Authorized Signatory		

(Dr. S. M. Nairkar)
Professor, CE-AMD

(Dr. S.K. Ahirwar)
Associate Professor, CE-AMD

(Dr. R. K. Khare)
Professor & Head, CE-AMD

DIRECTOR